DESIGN OF MIMO ANTENNA FOR BAND NOTCHED UWB APPLICATIONS

A project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

P.Vathsalya (318126512116)
G.V.Nagarjuna (318126512079)
D.Thirumalesh (318126512072)
K.kiran (318126512082)

Under the guidance of

Mr. Vijay Kumar Sahu **MTech(Ph.D)**
Assistant Professor

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)
(*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade*)
Sangivalasa, bheemilimandal, visakhapatnam dist.(A.P)
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PRAGNANAM BRAHMA
ANITS

CERTIFICATE

This is to certify that the project report entitled **"DESIGN OF MIMO ANTENNA FOR BAND NOTCHED UWB APPLICATIONS"** submitted by **P.Vathsalya (318126512116),G.V.Nagarjuna(318126512079), D.Thirumalesh (318126512079), K.Kiran (318126512082)** in partial fulfillment of the requirements for the award the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of bonafide work carried out under my guidance and super vision.

Project Guide

Mr. Vijay Kumar Sahu **MTech (Ph.D)**
Assistant Professor
Department of E.C.E
ANITS

Assistant Professor
Department of E.C.E.
Anil Neerukonda
Institute of Technology & Sciences
Sangivalasa, Visakhapatnam

Head of the Department

Dr. V.Rajyalakshmi
Professor &HOD
Department of E.C.E
ANITS

Head of the Department
Department of E C E
Anil Neerukonda Institute of Technology

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Project students
P.Vathsalya (318126512116)
G.V.Nagarjuna (318126512079)
D.Thirumalesh (318126512072)
K. Kiran (318126512082)

ABSTRACT

Spectrum from 3.1 to 10.6 GHz is released for commercial application, UWB techniques have drawn considerable attention due to the merits such as wide bandwidth, high data rate, and low cost. Moreover, designing the antenna in order to reject the interference with the existing wireless communication systems such as the Wireless Local Area Networks (WLAN) operating at 5.15-5.85 GHz, antennas are required to filter out the undesired band.

The Project aims in designing a compact band notched UWB MIMO antenna with two identical antenna elements. The antenna designed would be compared with the conventional center fed patch antenna. The designed antenna is aimed to possess polarization diversity along with the above said characteristics while taking proper care in ensuring minimal mutual coupling between the elements designed, as this would deteriorate the performance of the MIMO antenna. Results like return loss, VSWR, and gain would be presented.

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1.Antenna

1.1 Introduction

Communicationhasbecomethekeytomomentouschangesintheorganization of business and industries as they themselves adjust to the shift to aninformation economy. Information is indeed the lifeblood of modern economies andantennasprovidemother earth asolution toa wireless communicationsystem.

An antenna is a transducer designed to transmit or receive electromagneticwaves.Inotherwords,antennasconvertelectromagneticwavesintoelectricalcurrentsandviceversa.Theyareusedwithwavesintheradiopartoftheelectromagnetic spectrum, that is, radio waves, and are a necessary part of all radioequipment. Antennas have many uses: communication, radar, telemetry navigation,etc. The figure shows the output from a coherent source (e.g. an oscillator) is directedout into free space using an antenna. The signal source is linked to the antenna bysome kind of waveguide (microwave guide light fiber etc). The antenna acts as a sortof transformer. It takes the electromagnetic field pattern, moving along the guide andtransformsit intosome other pattern,which isradiated out intofreespace.

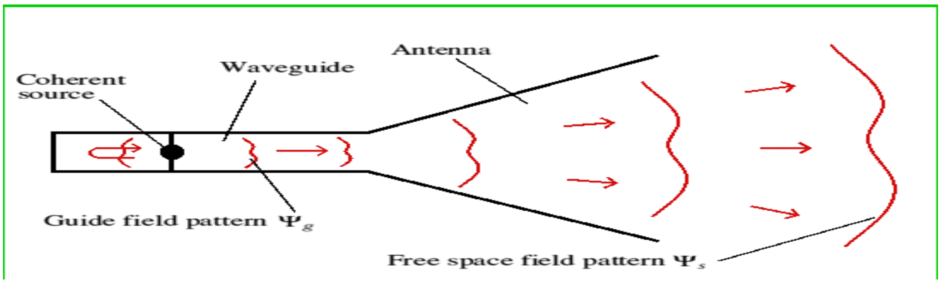


Fig1.1: Schematic ofan antennasystem

Usingthis simplepicture wecanestablishtwo basic propertiesof anyantenna

- An antenna itself does not generate any power. So, unless the antenna isimperfect and dissipates some power the total power carried by the guideand free space fields must be the same. Practically, all antennas tend to beslightly resistive. So some power is normally lost, but for now, we canassumeanyloss is small enough to ignore.
- Anantennaisareciprocaldevicei.e.,itbehavesinthesamewayirrespective of the way we pass signal power through it. This reciprocalbehavior is a useful

feature of a coherent antenna. It means that in principle,theonlydifferencebetweena‘transmitting’anda‘receiving’antennais thedirectionwe'vechosentopasssignals through it.

1.2TypesofAntennas:

There are two fundamental types of antenna directional patterns, which withreferencetoaspecifictwo-dimensionalplane(usually horizontal[paralleltotheground][or vertical perpendicular totheground])areeither:

1. Omni-directional (radiates equally in all directions), such as a vertical rod (inthe horizontalplane) or
2. Directional(radiatesmorein onedirectionthan intheother)

In colloquial usage "omnidirectional” usually refers to all horizontal directionswith reception above and below the antenna being reduced in favor of better receptionnearthehorizon.Adirectionalantennausuallyreferstoonefocusinganarrowbeamin a single specific direction such as a telescope or satellite dish, or, at least, focusingin a sector such as a 120° horizontal fan pattern in the case of a panel antenna at a cellsite. The present antenna in the thesis i.e. Microstrip antenna is an omnidirectionalantenna which radiates normal to the patch surface into the upper hemisphere (180° inelevationplane)and 360in theazimuth plane

BasicModelsof Antennas:

Therearemanyvariations ofantennas.Beloware afewbasicmodels.

- The **Isotropic radiator** is a purely theoretical antenna that radiates equally inall directions. It is considered to be a point in space with no dimensions and nomass. This antenna cannot physically exist but is useful as a theoretical modelforcomparisonwithall otherantennas.Mostantennas“ gains are measured with reference to an isotropic radiator and are rated in dB(decibelswith respect toan isotropicradiator).
- The**Dipoleantenna**issimplytwowirespointedinoppositedirectionsarranged either horizontally or vertically, with one end of each wire connectedto the radio and the other end hanging free in space. Since this is the simplestpracticalantenna.

- The **Yagi-Uda**antenna is a directional variation of the dipole with parasiticelements added which are functionally similar to adding a reflector and lenses(directors)tofocus afilament light bulb.
- Therandom**wireantenna**issimplyaverylong(atleastone-quarterwavelength) wire with one end connected to the radio and the other in freespace, arranged in any way most convenient for the space available. Foldingwillreduceeffectivenessand maketheoreticalanalysisextremelydifficult.
- The **Parabolic antenna** consists of an active element at the focus of aparabolic reflector to reflect the waves into a plane wave. Like the horn, it isusedforhighgain, microwaveapplications,such as satellitedishes
- **Patch antenna** consists mainly of a square conductor mounted over aground plane. Another example of a planar antenna is the tapered slot antenna(TSA),as the Vivaldi-antenna.

1.3 BasicAntennaParameters:

1.3.1 RadiationPattern:

An Antenna radiation pattern is definedas “a mathematical function or agraphical representation of the radiation properties of the antenna as a function ofspace coordinates. In most cases, the radiation pattern is determined in the far-fieldregion and is represented as a function of directional coordinates. The figure shows asymmetricalthree-dimensionalpolar patternwithanumberofradiation lobes.

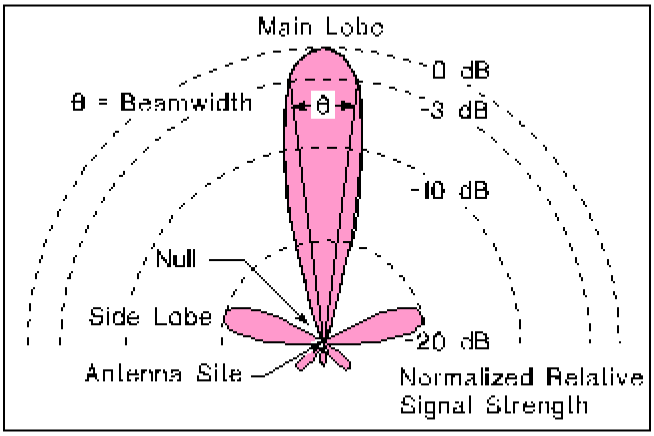


Fig1.2:Radiationlobesofanantennapattern

1.3.2 Beam width

The beamwidthofa patternisdefinedastheangular separationbetweentwo identical points on the opposite side of the pattern maximum. One of the mostwidely used beam widths is the Half-Power Beam width (HPBW). Another importantBeam width is the angular separation between the first nulls of the pattern, and it isreferredto astheFirstNullBeamwidth(FNBW).BothHPBWandFNBWareshowninfigure1.3

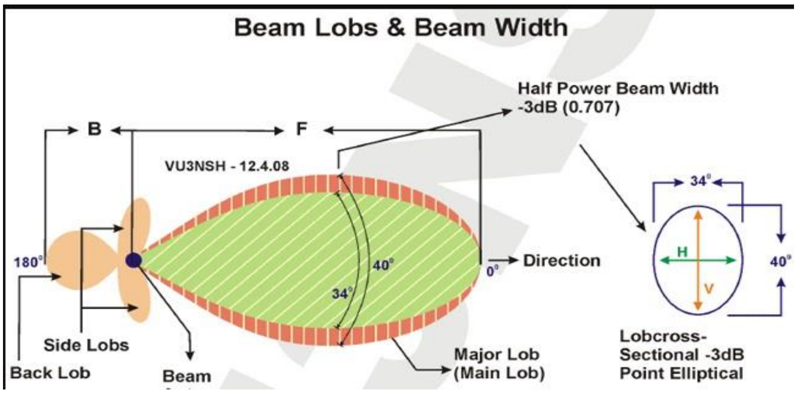


Fig1.3:BeamwidthofanAntenna

1.3.3 Directivity:

The directivity of an antenna is “the ratio of the radiation intensity in a givendirection from the antenna to the radiation intensity averaged over all directions". Theaverage radiation intensity is equal to the total power radiated by the antenna dividedby4π.

$$D=\frac{U}{Uav}=\frac{4\pi U}{Prad} \qquad (1.1)$$

1.3.4 Gain:

The gain of the antenna is closely related to the directivity, it is a measurethat takes into account the efficiency of the antenna as well as its directionalcapabilities. A gain of an antenna is defined as “the ratio of intensity in a givendirectionto theradiationintensitythat would beobtained if thepower accepted bythe antenna were radiated isotropically”. The radiation intensity corresponding to theisotropically radiated power is equal to the power accepted by the antenna divided by4π.

Gain $=4\frac{\pi(radiation\ intensity)}{total\ input\ power}=4\frac{\pi U(\theta,\varphi)}{p}$ (1.2)

1.3.5 EffectiveLength:

The effective length represents the antenna in its transmitting and receivingmodes and it is particularly useful in relating the open-circuit voltage Voc of receivingantennas.This relation can beexpressed as

$$Voc=EixLe \tag{1.3}$$

Where Voc=open-circuit voltage at antenna terminals,Ei-incident electric field

Le=vectoreffectivelength

1.3.6 AntennaEquivalentAreas:

These equivalent areas are used to describe the power capturing characteristicsof the antenna when a wave impinges on it. The different antenna equivalent areas arescattering area, loss area, capture area. The scattering area is defined as the equivalentarea when multiplied by the incident power density is equal to the scattered or re-radiated power. The loss area is defined as the equivalent area when multiplied by theincident power density leads to the power dissipated as heat through a load. Thecapture area is defined as the equivalent area when multiplied by the incident powerdensityleadstothetotalcaptured,collected,orintercepted bytheantenna.Ingeneral

Capturearea=Effectiveareaofscatteringarea+loss area

1.3.7Antenna Efficiency:

ThetotalefficiencyE0isusedtotakeintoaccountlossesattheinputterminalsandwithinthestructureoftheantenna.Suchlossesmaybeduetoreflectionsbecause of the mismatchbetween thetransmission line and the antennaandIR losses dueto theconductors and dielectric.

In generaloverallefficiencycanbewrittenas

$$E0=ErEcEd \tag{1.4}$$

WhereE0=Totalefficiency.

Er = Reflection efficiency
Ec = conduction efficiencyEd = dielectric efficiency

1.3.8 Inputimpedance:

The input impedance of an antenna is impedance presented by an antenna atitsterminals. The antennaimpedanceZAcan beexpressed as,

$$ZA=RA+jXA\Omega \qquad (1.5)$$

Where RA is the antenna resistance in ohms andXA is the antenna reactance inOhms.Theradiation Resistanceis expressed as

$$RA=R_r+R_L\ \Omega \qquad (1.6)$$

Where $R_r$istheradiationresistanceandR_L isthelossresistance.Theradiationresistance is associated with the radiation of real power. For a lossless antenna, theinput resistance reduces the radiation resistance. The input impedance is also the ratioof the voltage to current at its terminal or the ratio of the appropriate electric andmagneticfields at a point.

1.3.9 Bandwidth:

Thebandwidthofanantennaisthatfrequency rangeoverwhichitwillperform within certain specified limits. These limits are with respect to impedancematch,gain, and/or radiation pattern characteristics.

Typicalspecificationlimitsare

- An impedance mismatch of less than 2:1 relative to some standard impedancesuchas 50 ohms
- Aloss ingain or efficiencyof nomorethan3 dB.
- A directivity pattern whose main beam is 13 dB greater than any of the sidelobes,and aback lobe atleast 15dBbelow themain beam
- Bandwidth is measured by changing the frequency of a constant strength test nabove and below center frequency and measuring power output. The high andlow frequencies, where power is one-half (-3 dB) of what it was at the

center,define the bandwidth. It is expressed as frequency (high minus low) or inpercentage(high-low/centre*100%).Figure1.4showsthetypicalbandwidthplotof themicrostrip antenna.

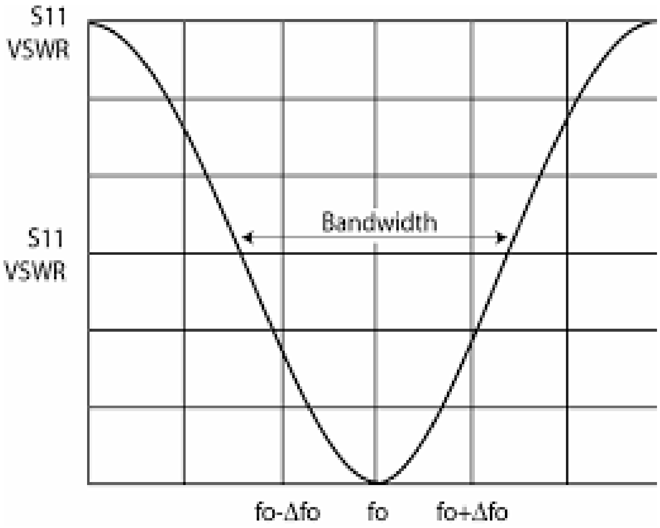


Fig1.4:Bandwidth oftheantenna

1.3.10ReflectioncoefficientandReturnloss:

Reflection Coefficient shows what fraction of an incident signal is reflectedwhen a source drives a load. A **reflection coefficient** magnitude of zero is a perfectmatch; a value of one is a perfect reflection. The symbol for the reflection coefficientis uppercase Greek Letter gamma (Γ). Note that the reflection coefficient is a vector,soitincludesanangle.UnlikeVSWR,thereflectioncoefficientcandistinguishbetween short and open circuits. A short circuit has a value of -1(1 at an angle of 180degrees), while an open circuit is one at an angle of 0 degrees. Quite often we refer toonlythe magnitudeof thereflection coefficient.

ReturnLossshowsthelevelofthereflectedsignalwithrespecttotheincident signal in dB. The negative sign is dropped from the return loss value, so alarge value for return loss indicates a small reflected signal. The **return loss** of a loadismerelythemagnitude ofthe reflectioncoefficient expressed indecibels.

Thecorrectequationfor returnloss is:

$ReturnLoss=-20Log(\Gamma)$ (1.7)

Thus, in its correct form, return loss will usually be a positive number. If it's not,you can usually blame measurement error. The exception to the rule is something withnegative resistance, which implies that it is an active device (external DC power isconvertedto RF) and it is potentiallyunstableit could oscillate).

1.3.11VoltageStandingWaveRatio(VSWR):

VSWR describes how much energy is reflected from the antenna because ofimpedance mismatching. A perfectly impedance matched antenna would have VSWRequal to one. Return loss (RL) is often used as it illustrates the gain reduction thatwould be introduced due to the mismatch of the antenna. VSWR is very important forwireless communications because the received signals from the satellites are usuallyvery weak (on the order of -160 dB) and reflections are undesired on the transmissionline connecting the antenna and the receiver. VSWR less than 2:1 (equivalent to areturn loss of -9.5dB) is considered to be acceptable for most wireless applicationsbecause the time delay of any reflections is typically small, thus providing smallamounts of error within the receiver. A lower VSWR may be required for particularlyhigh-performance applications and unique installations

$$\mathrm{VSWR} = (1+\Gamma) \mid (1-\Gamma) \qquad (1.8)$$

1.3.12 Polarization:

A radiated waves polarization is determined by the direction of the lines offorce making up the electric field. If the lines of electric force are at right angles to theEarth's surface, the wave is vertically polarized. If the lines of electric force areparalleltotheEarth'ssurface,thewaveishorizontallypolarizedasshowninFigure 1.5. When a single-wire antenna extracts (receives) energy from a passing radio wave,maximum pickup results if the antenna is oriented in the same direction as the electricfieldcomponent.

Averticalantennareceivesverticallypolarizedwaves,andahorizontalantenna receives horizontally polarized waves. If the field rotates as the waves travelthroughspace,bothhorizontalandverticalcomponentsofthefieldexist,andthewaveis ellipticallypolarized.Generally,theantennaradiatesanellipticalpolarization, which is defined by three parameters: axial ratio, tilt angle, and sense ofrotation. When the axial ratio is infinite or zero, the polarization becomes linear withthe tilt agile defining the orientation. The quality of linear polarization is usuallyindicated by the level of the cross-polarization. For the unity axial ratio, a perfectcircularpolarization results andthe tiltangle is not applicable.

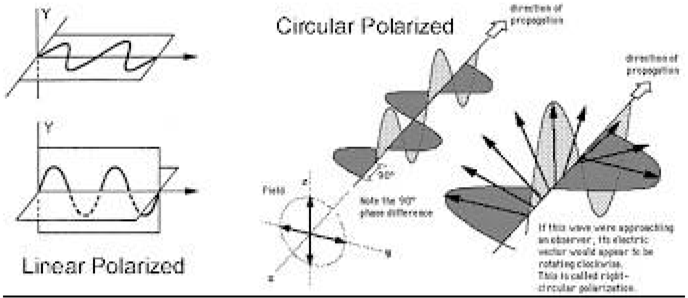


Fig1.5: Linearand circularpolarizationofanantenna

In general, the axial ratio is used to specify the quality of circularly polarizedwaves as shown. Antennas produce circularly polarized waves when two orthogonalfieldcomponents with equal amplitude but inphasequadratureareradiated.

1.3.13 Axialratio:

TheAxialRatioistheratiooforthogonalcomponentsofanE-field.Acircularly polarized field is made up of two orthogonal E-field components of equalamplitudesand90degreesoutofphase).Becausethecomponentsareequalmagnitude, the Axial Ratio is 1 (or 0 dB).In order to check the polarization of thedesigned antenna, the axial ratio (AR) was calculated and analyzed. The axial ratio, asdefined, is the ratio of the major axis to the minor axis of the tilted ellipse formed bytheelectricfield of ellipticallypolarized waves.

$$\text{Axialratio (AR)} = \text{majoraxis} / \text{minoraxis} \quad 1 \leq AR \leq \infty \qquad (1.9)$$

1.4EQUIVALENTDIAGRAMOFANANTENNA:

A transmission-line Thevenin equivalent of the antenna system is shown infigure Source is represented by an ideal generator, the transmission line is representedby a line with characteristics impedance Zs, and the antenna is represented by a loadZLwhere,

$$ZL = R_L + jX_L \qquad (1.10)$$

TheloadresistanceRLisusedtorepresenttheconductionanddielectriclossesassociated with antenna structure while R_r referred to as the radiation resistance, isused to represent radiation by the antenna. The reactance XL is used to represent theimaginary part of the impedance associated with radiation by the antenna. Taking intoaccounttheinternalimpedanceofthesourceandneglectinglineandreflection(mismatch)losses,maximumpowerisdeliveredtotheantennaunderconjugatematching.

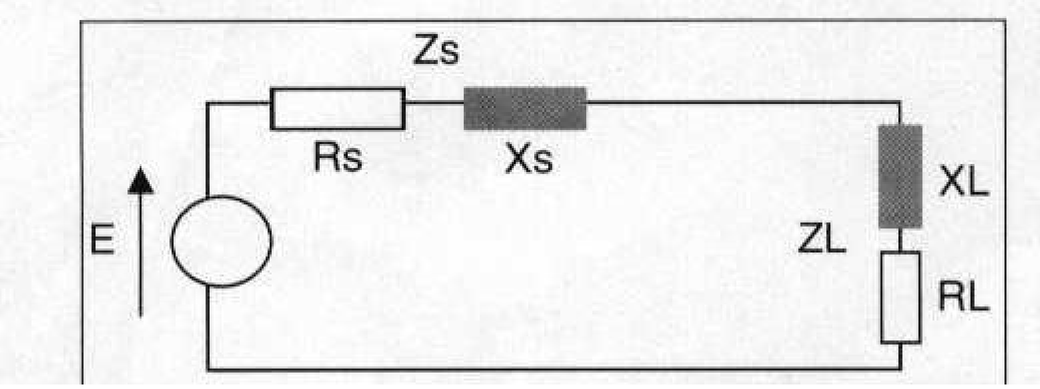


Fig1.6:Equivalentdiagram ofanantenna

2.Microstrip antenna

2.1 Introduction:

Microstrip antennas are attractive due to their lightweight, conformability, andlow cost. These antennas can be integrated with printed strip-line feed networks andactive devices. This is a relatively new area of antenna engineering. The radiationpropertiesofmicrostrip structures havebeen known sincethe mid-1950s.

Theapplicationofthistypeofantennasstartedintheearly 1970swhenconformal antennas were required for missiles Rectangular and circular microstripresonant patches have been used extensively in a variety of array configurations. Amajor contributing factor for recent advances of microstrip antennas is the currentrevolutioninelectroniccircuitminiaturizationbroughtaboutby developmentsinlarge scale integration. As conventional antennas are often bulky and costly part of anelectronicsystem,microstripantennasbasedonphotolithographictechnology areseenas anengineeringbreakthrough.

Initsmostfundamentalform,aMicrostripPatchantennaconsistsofaradiating patch on one side of a dielectric substrate which has a ground plane on theother side. The patch is generally made of conducting material such as copper or goldand can take any possible shape. The radiating patch and the feed lines are usuallyphotoetched on the dielectric substrate.

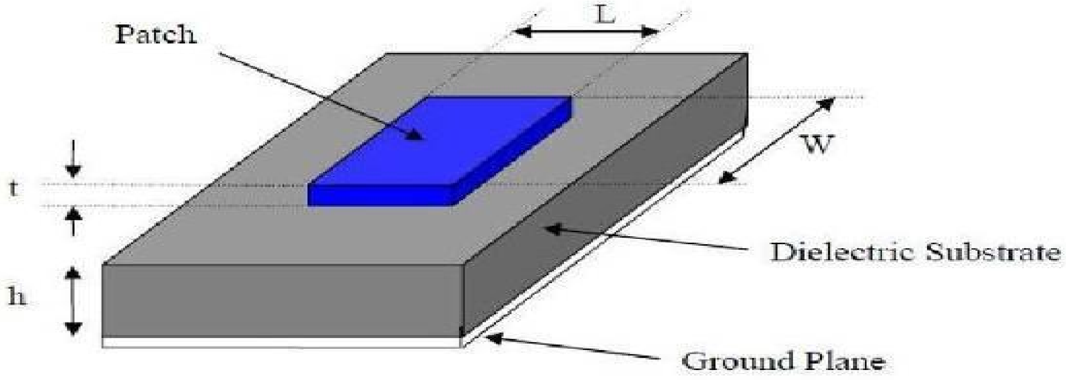


Fig2.1:structureof Microstrip patchantenna

Inordertosimplifyanalysisandperformanceprediction,thepatchisgenerallysquare,rectangular,circular,triangular,andellipticalorsomeothercommonshape.Forarectangularpatch, thelengthLofthepatchisusually$0.3333\lambda 0<L<0.5\lambda$where $\lambda 0$isthefree-spacewavelength.Thepatchis selected to be very thin such that $t<<\lambda 0$ (Where is the patch thickness).The heightof the dielectricsubstrate(h)isusually$0.003\ \lambda 0<= h$

<=0.05λ0.Thedielectricconstantofthesubstrate(ε_r)is typicallyin therangeof2.2<=ε_r<=12.

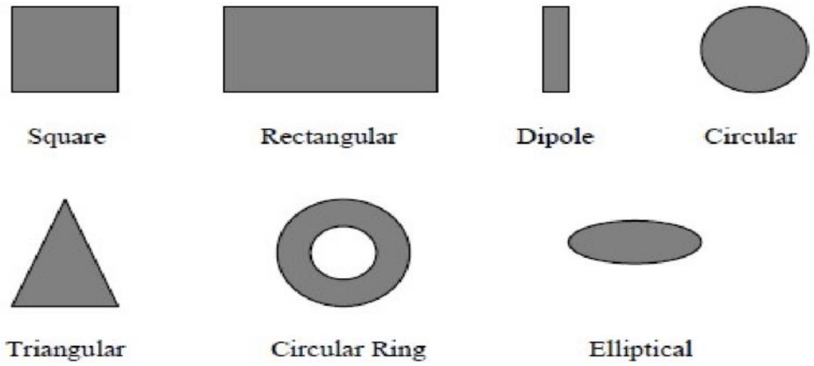


Fig2.2:Commonshapeofmicrostrippatchelements

Microstrippatchantennasradiateprimarilybecauseofthefringingfieldsbetween the patch edge and the ground plane. For good antenna performance, a thickdielectric substrate having a low dielectric constant is desirable since this providesbetterefficiency.largerbandwidthandbetterradiation.However,suchaconfiguration leads to larger antenna size. In order to design a compact Microstrippatch antenna, substrates with higher dielectric constants must be used which are lessefficientandresultinnarrowbetweentheantennadimensionsandantennaperformance bandwidth. Hence a trade-off must be realized between the antennasdimensionsandantennasperformance

2.2 Microstripstructures:

Amicrostripstructureismadewithathinsheetoflow-lossinsulatingmaterial called the dielectric substrate. It is completely covered with metal on theinside, called the ground plane, and partly metalized on the other side, where thecircuit or antenna shapes are printed. Components can be included in the circuit eitherby it planting lipid components (resistors, inductors, capacitors, semiconductors, andferrite devices) or by realizing them directly within the circuit. Eachpart of themicrostripstructurewillbeexplained in detail as follows:

2.2.1 DielectricSubstrate:

The dielectric substrate is the mechanical backbone of the microstrip circuit Itprovides stable support for the conductor strips and patches that make up conductinglines, resonators, and antennas. It ensures that the components that are implanted ireproperly located and firmly held in place, just as in printed circuits for electronics atlower frequencies. The substrate also fulfills an electric function by concentrating theelectromagnetic fields and preventing unwanted radiation in circuits. The dielectric isan integral part of the connecting transmission lines and deposited components itspermittivity and thickness determine the electrical characteristics of the circuit or oftheantenna.

2.2.2 conductor layers

Nowadays, many commercial suppliers provide a wide range of microstripsubstratesalreadymetalizedonbothfaces.Theconductorontheupperfaceischemically etched to realize the circuit pattern by a photography technique. A mask ofthe circuit of the antenna is drawn, generally at a convenient scale, and then reducedandplacedinclosecontactwithaphotoresistivelayer,whichhaspreviouslydepositedon top ofthe metalized substrate.

The lower metal part is the ground plane. The ground plane, besides acting asmechanicalsupport, provides for the integration of severalcomponentsand servesalso asa heat sinkandde-bias returnfor activedevices.Theresulting sandwich isthen exposed to ultraviolet rays, which reach the photosensitive layer where it is notcoveredbythemask.Theexposedpartsareremovedbythephotographicdevelopment, and the metal cover is etched away from the exposed area. This processis called the subtractive process. Alternatively, one may wish to use a bare dielectricsubstrateasastartingmaterialanddepositmetalcitherbyevaporationorbysputtering through the holes in the mask. This is called the additive thin film process.In the thick-film process, a metallic paste is squeezed through the holes in a maskdeposited over a silkscreen. The latter approach, however, is less accurate and itseldomusedat veryhighfrequencies.

2.3WavesonMicrostrip:

Themechanismsoftransmissionandradiationinamicrostripcanbeunderstood by considering a point current source (Hertz dipole) located on top of thegrounded dielectric substrate This source radiates electromagnetic waves. Dependingon the direction toward which waves are transmitted, they fall within three distinctcategories, each of whichexhibits different behaviors.

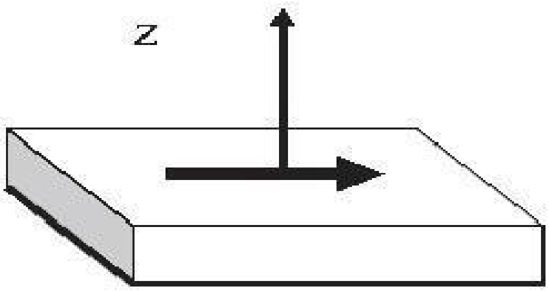


Fig2.3: Hertzdipoleonamicrostripsubstrate

2.3.1 SurfaceWaves:

The waves transmitted slightly downward, having elevation angles between π/2 and π- arcs in (1/ √ εr), meet the ground plane, which reflects the, and then meet thedielectric-to-air boundary,which also reflects them (total reflection condition). Themagnitude of the field amplitudes builds up for some particular incidence anglesthatlead to the excitation of a discrete set of surface wave modes, which are similartothe modes in metallic waveguide.

Thefieldsremainmostlytrappedwithinthedielectric,decayingexponentially above the interface. The vector alpha, pointing upward, indicates thedirection of the largest attenuation. The wave propagates horizontally along, withlittle absorption in a good quality dielectric. With two directions ofand orthogonalto each other, the wave is a non-uniform plane wave. Surface waves spread out incylindrical fashion around the excitation point, with field amplitudes decreasing withdistance (r), says 1/r, more slowly than space waves. The same guiding mechanismprovidespropagation within optical fibers.

Surface waves take up some part of the signal's energy, which does not reachthe intended user. The signal's amplitude is thus reduced, contributing to n apparentattenuationoradecreaseinantennaefficiency.Additionally,surfacewavesalsointroducespuriouscouplingbetweendifferentcircuitsofantennaelements.Thiseffect severely degrades the performance of microstrip filters because the parasiticinteractionreduces the isolation in the stop bands.

In large periodic phased arrays, the effect of surface wave coupling becomesparticularly obnoxious,and thearray canneither transmitnor receivewhen it ispointedatsomeparticulardirections(blindspots).Thisisduetoaresonancephenomenon when the surface waves excite in synchronism the Floquet modes of theperiodic structure Surface waves reaching the outer boundaries of an open microstripstructure are reflected and refracted by the edges. The diffracted waves provide anadditionalcontributiontoradiation,degradingtheantennapatternbyraisingthesidelobe and the cross-polarization levels. Surface wave effects are mostly negative,forcircuits andforantennas, so theirexcitation should besuppressedifpossible.

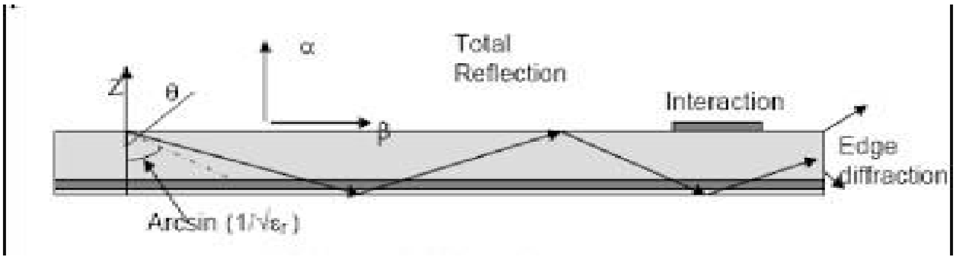


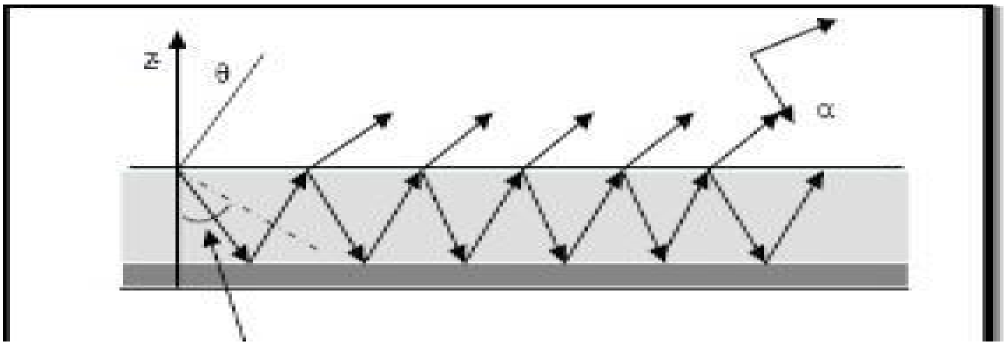
Fig2.4:Surfacewaves

2.3.2 Leaky waves:

Wavesdirectedmoresharplydownward,with πanglesbetween π arcsin1|$\sqrt{\varepsilon_r}$and π are alsoreflected bythegroundplanebutonlypartiallybythedielectric-to-air boundary. They progressively leak from the substrate into the air, hence theirname leaky waves, and eventually contribute to radiation. The leaky waves are alsononuniform plane waves for which the attenuation directionpoints downward, whichmay appear to be rather odd; the amplitude of the waves increases as one moves awayfromthedielectricsurface.

This apparent paradox is the field amplitude increase in the move away fromsubstrate became the wave radiates from a poi where the signal amplitude is largerSince the structure is finite this apparent divergent behavior can only exist locally andthewavevanishes abruptlyas onecrosses thetrajectoryof thefirst ray.

In more complex structures made with several layers of different dielectrics,leaky waves can be used to increase the apparent antenna size and provide largergains. This occurs for favorable stacking arrangements and at a particular



frequency.Conversely,leakywavesarenot excited insome othermultilayerstructures.

Fig2.5:Leakywaves

2.3.3 GuidedWaves:

when realizing printed circuits, one locally adds a metal layer on top of thesubstrate which modifies the geometry, introducing an additional reflecting boundary.Waves directed into the dielectric located under the upper conductor bounce back andforth on the metal boundaries, which form a parallel plate waveguide. The waves inthe metallic guide can only exist for some Particular values of the angle of incidence,forming a discrete set of waveguide modes. The guided waves provide the normaloperation of all transmission lines and circuits, in which the electromagnetic fields aremostly concentrated in the volume below the upper conductor. On the other hand, thisbuild-up of electromagnetic energy is not favorable for patch antennas, which behaveliketests with alimited frequencybandwidth.

2.4 MicrostripAntennaTypes:

2.4.1 MicrostripDipole:

Thesmallsizeofthedipoleantennasmakesthemattractiveformanyapplications but also results in the very narrow frequency bandwidth. No transversecurrentflows onanarrowdipole, so the cross-polarization levelis inherentlylow.

A microstrip dipole is usually fed by a balanced feed, for instance, a paralleltwo-wire line printed on the substrate or two wires connected through the substrate.Transitionsorbalunsmustthenbeincorporatedtoconnectthefeedtoamicrostriplineortoacoaxialline,whichisbothinherentlyunbalancedtransmissionlines.

Alternatively,dipolesmayalsobefedbyelectromagneticcouplingwithembeddedfeedlines.

2.4.2 MicrostripPatch:

Printed patch antennas use radiating elements of a wide variety of shapes.Square,rectangle,circle,ring,trianglemorecomplexgeometricalfigures,andacombination of simpler shapes are also used for the applications. The selection of aparticular shape depends on the parameters one wishes to optimize bandwidth, sidelobescross-polarization,and antennasize.

Microstrip patches present a somewhat broader relative bandwidth than dipoles,of the order of a few percent. In contrast to thin dipoles, patches may excite somesurfacecurrentflowingacrossthetransversedirection,whichthenradiatesanunwanted cross-polarized component. Its amplitude is critically dependent on the kindoffeedand its locationwith respect to the axesofthe patch.

2.4.2.1 RectangularPatches

The geometry-shape most commonly used to realize microstrip patch antennasare the rectangle. A rectangular patch can be considered to be an open-ended sectionof transmission line of length L and width W. The fringing fields at the two ends areaccountedforbyaddingequivalentLat both ends.

$$Fm=\frac{mco}{|(L+\Delta L)}$$

With the integer m=1,2,3($\neq 0$) and relative permittivity,εr is given by the equationwhere Co is free space speed of light, and εreff is the effective permittivity of thesubstrate. This expression is for resonant modes in which surface current is mostlylongitudinal, more complexresonance patterns are obtained for higher-order modeson widelines.

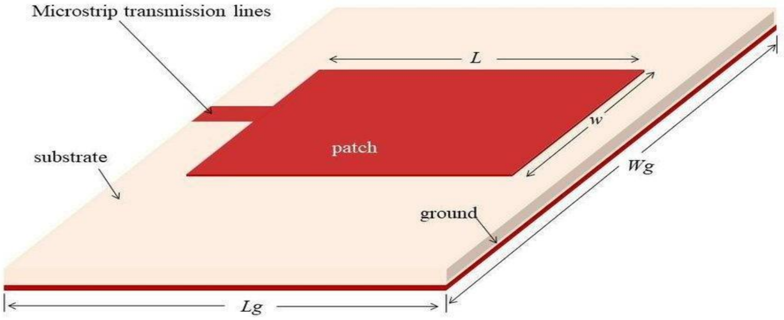


Fig2.6:RectangularPatch

The lines of surface current correspond, respectively, to the TM$_{100}$ and theTM$_{010}$
theTM$_{110}$foranequivalentsureshapedcavityhavingperfectmagneticconductor(PMC) sidewalls.

2.4.2.2 CircularPatches:

Circular patches were reported to lose energy by radiation and thus providelarge-quality factors than rectangular pulses. The resonant frequency is determined byassuming that a perfect wall (PMC) extends under the edges of the patch Fringingfields are taken into account by defining effective resonator radius a_e which is slightlylargerthan thephysical radius (a).

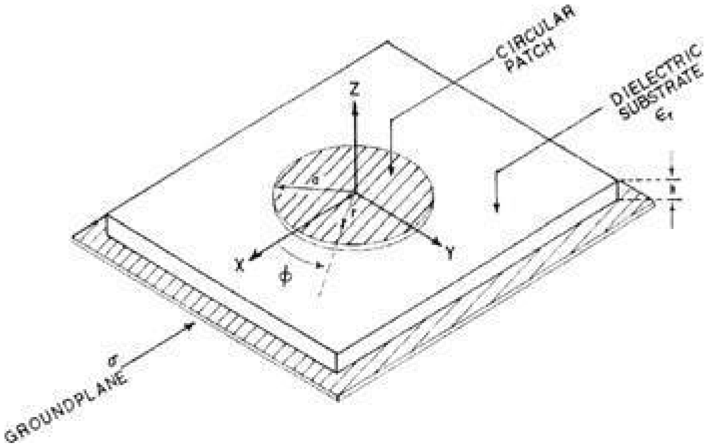


Fig2.7:Circularpatch

2.4FeedingTechniques:

Microstrip patch antennas can be fed by a variety of methods. These methodscan be classified into two categories contacting and non-contacting. In the contactingmethod, the RF power is fed directly to the radiating patch using a connecting elementsuchasamicrostripline.Inthenon-contactingscheme,electromagneticfieldcoupling is done to transfer power between the microstrip and the radiating patch. Thefour most popular feed techniques used are the microstrip line, coaxial probe (bothcontacting schemes), aperture coupling, and proximity coupling (both non-contactingschemes).

2.4.1 MicrostripLineFeed:

In this type of feed technique, a conducting strip is connected directly to theedge of the Microstrip patch. The conducting strip is smaller in width as compared tothe patch and this kind of feed arrangement has the advantage that the feed can beetchedon the samesubstrate toprovideaplanar structure.

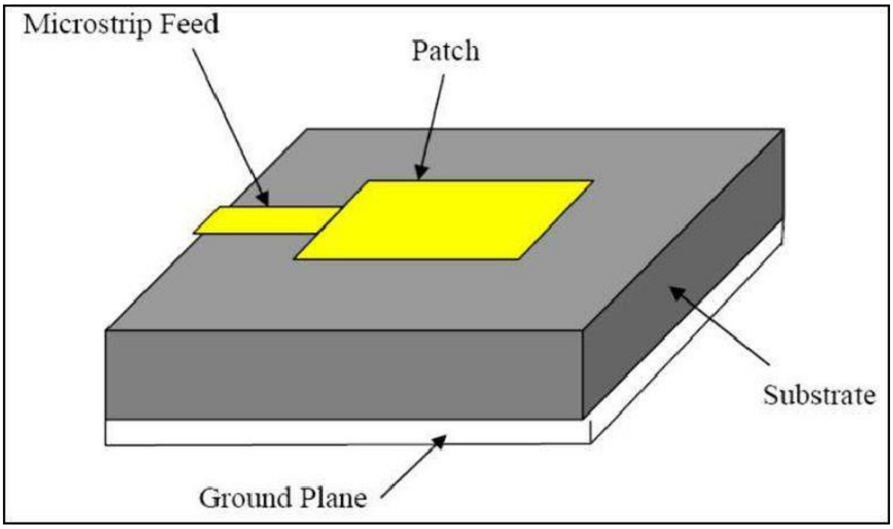


Fig2.8Microstriplinefeed

The purpose of the inset cut in the patch is to match the impedance of the feedlinetothepatchwithouttheneedforanyadditionalmatchingelement.Thisisachieved by properly controlling the inset position. Hence this is an easy feedingscheme since it provides ease of fabrication and simplicity in modeling as well asimpedance matching. However as the thickness of the dielectric substrate being used,it increases surface waves and spurious feed radiation also increases, which hampersthebandwidthoftheantenna.Thefeedradiationalsoleadstoundesiredcross-polarizedradiation.

2.4.2 CoaxialFeed:

The Coaxial feed or probe feed is a very common technique used for feedingMicrostrippatchantennas.AsseenfromFigure-2.9,theinnerconductorofthecoaxial connector extends through the dielectric and is soldered to the radiating patch,whiletheouterconductor is connected to theground plane.

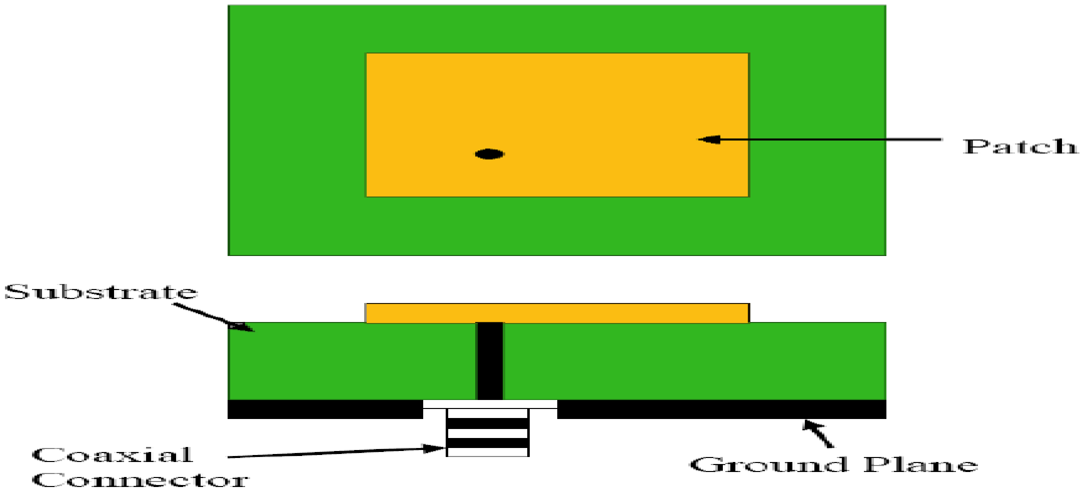


Fig2.9:ProbefedRectangularMicrostrip PatchAntenna

The main advantage of this type of feeding scheme is that the feed can beplacedatanydesiredlocationinsidethepatchinordertomatchwithitsinputimpedance. This feed method is easy to fabricate and has low spurious radiation.However, a major disadvantage is that it provides narrow bandwidth and is difficult tomodel since a hole has to be drilled in the substrate and the connector protrudesoutsidethegroundplane,thusnotmakingitcompletelyplanerforthicksubstrates(h $> 0.020\lambda_0$). Also, for thicker substrates the increased probe length makes the inputimpedance more inductive, leading to matching problems. It is seen above that formthick dielectric substrate, which provides broad bandwidth; the microstrip line feedandthe coaxial feed suffer from numerousdisadvantages.

2.4.3 ApertureCoupledFeed:

In this type of feed technique, the radiating patch and the microstrip feed lineare separated by the ground plane. Coupling between the patch and the feed line ismadethrough aslot or anapertureinthegroundplane.

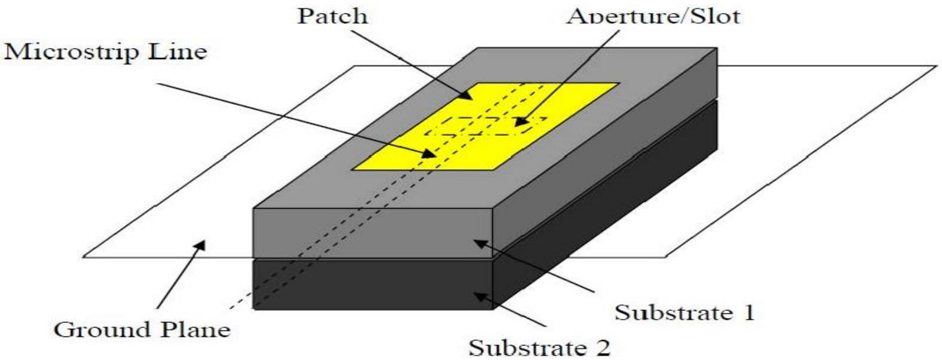


Fig2.10: Aperture-coupledfeed

The coupling aperture is usually cantered under the patch, leading to lowercross-polarization due to the symmetry of the configuration. The amount of couplingfrom the feed line to the patch is determined by the shape, size, and location of theaperture.Sincethegroundplaneseparatesthepatchandthefeedline,spuriousradiation is minimized. The major disadvantage of this feed technique is that it isdifficult to fabricate due to multiple layers which also increases the antenna thickness.Thisfeedingscheme alsoprovides anarrow bandwidth.

2.4.4 ProximityCoupledFeed:

Thistypeoffeedtechniqueisalsocalledastheelectromagneticcouplingscheme. Two dielectric substrates are used such that the feed line is between the twosubstrates and the radiating patch is on top of the upper substrate. The main advantageof this feed technique is that it eliminates spurious feed radiation and provides veryhigh bandwidth (as high as 13%), due to the overall increase in the thickness of themicrostrippatchantenna.Thisschemealsoprovideschoicesbetweentwodifferent dielectricmedia,

oneforthepatchandoneforthefeedlinetooptimizetheindividualperformances.

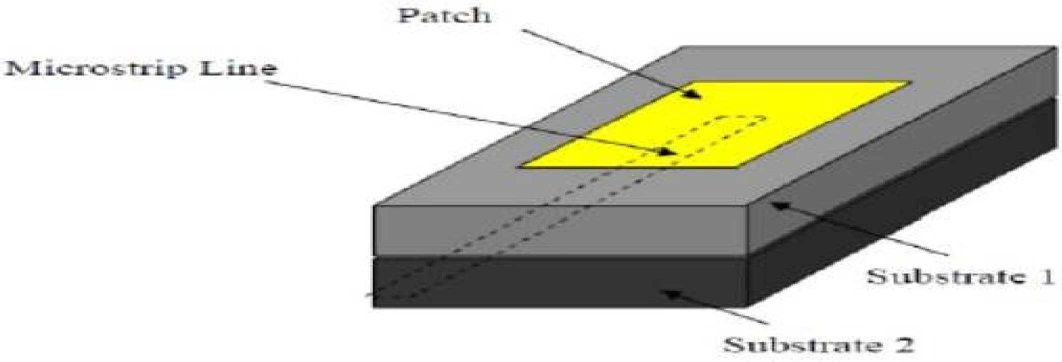


Fig2.11Proximity-coupledFeed

2.5 MethodsofAnalysis:

There are many methods of analysis for microstrip antennas. The most popularmodelsarethetransmission-line,cavity,andfull-wave(whichincludeprimarilyintegral equations/Moment Method). The transmission-line model is the easiest of all,it gives good physical insight, but is less accurate and it is more difficult to modelcoupling Compared to the transmission-line model, the cavity model 15 more accuratebut at the same time more complex. However, it also gives good physical insight andisratherdifficult tomodel coupling, although ithas been usedsuccessfully.

The full-wave models are very accurate, very versatile, and can treat singleelements, finite and infinite arrays, stacked elements, arbitrarily shaped elements, andcoupling. However, they are the most complex models and usually give less physicalinsight. The rectangular patch is by far the most widely used configuration. It is veryeasy to analyze using both the transmission-line and cavity models, which are mostaccurate for thin substrates. We begin with the transmission-line model because it iseasierto illustrate.

2.5.1 Transmission-LineModel:

The transmission-line model is the easiest of all but it yields the least accurateresults and it lacks versatility. Basically the transmission-line model represents themicrostrip antenna by two slots, separated by a low-impedance transmission line oflengthL.

2.5.1.1 Fringingeffects:

The dimensions of the patch are finite along the length and width: the fields atthe edges of the patch undergo fringing. The amount of fringing is a function of thedimensionsofthepatchandtheheightofthesubstrate.FortheprincipalE-plane (XY-plane) fringing is a function of the ratio of the length of the patch L to the heighth of the substrate (L/h) and the dielectric constant antennas of the substrate. Since formicrostripantennasL/h>>1,fringingisreduced. Thesameapplies forthewidth.

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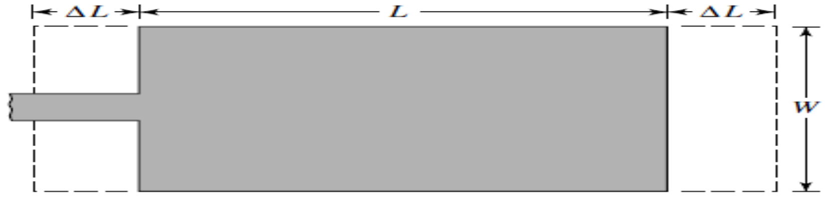
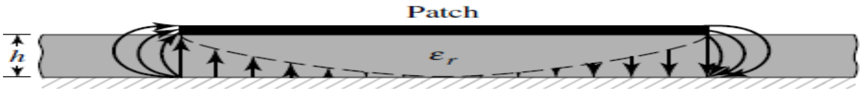


(a) Top view



(b) Side view

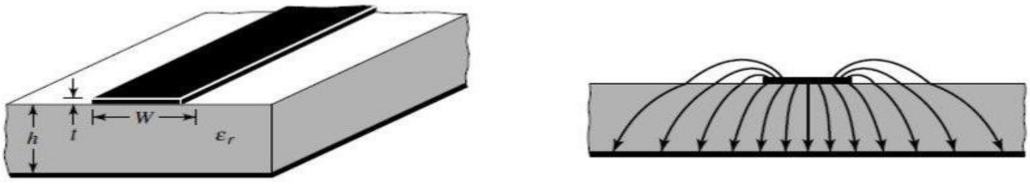
Fig 2.12: Physical and effective lengths of rectangular microstrip patch

Theabovefigureshowsthenon-homogeneouslineoftwodielectrics, typically the substrate and air. Most of the electric field lines reside in the substrateand parts of some lines exist in the air. As W/h>>1 and$_r$>>1 the electric field linesconcentrate mostly in the substrate. Fringing, in this case, makes the microstrip linelook wider electrically compared to its physical dimensions. Since some of the wavestravelinthesubstrateandsomeinair,aneffectivedielectricconstantε r $_{eff}$isintroduced to account for fringing and the wave propagation in the line is shown inFigure 2.12. The effective dielectric constant has values in the range of 1<ε_{eff}<ε_rTheeffectivedielectricconstantisalsoafunctionoffrequency,asthefrequencyofoperationincreases,mostoftheelectricfieldlinesconcentrateinthesubstrate.

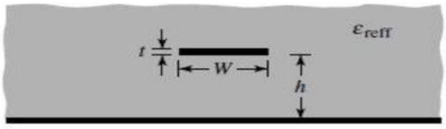
2.6.1.2 EffectiveLength,ResonantFrequency,andEffectiveWidth:

Because of the fringing effects, electrically the patch of the microstrip antennalooks greater than its physical dimensions. The dimensions of the patch along itslength have been extended on each end by a distance, which is a function of theeffective dielectric constant$\varepsilon_{reff}$and the width-to-height ratio (W/h) is given. Since thelength of the patch has been extended by AL on each side, the effective length of thepatch isnow

$$L_{eff}=L+2\Delta L$$



(a) Microstrip line (b) Electric field lines



(c) Effective dielectric constant

Fig2.13Microstriplineanditselectricfieldlinesandeffectivedielectricconstant geometry.

2.6.2 CavityModel:

Although the transmission line model discussed in the previous section is easyto use, it has some inherent disadvantages: Specifically, it is useful for patches ofrectangular design and it ignores field variations along the radiating edges. Thesedisadvantages can be overcome by using the cavity model. A brief overview of thismodel is given below. In this model, the interior region of the dielectric substrate ismodeled as a cavity bounded by electric walls on the top and bottom. The basisforthisassumption is the followingobservations forthin substrates the

- Since the substrate is thin the fields in the interior region do not vary much inthez-direction, it normal to the patch.
- Theelectricfieldiszdirectedonly,andthemagneticfieldhasonly thetransversecomponentsH,andH,intheregionboundedbythepatchmetallization and the ground plane. This observation provides for the electricwalls at thetop and thebottom.

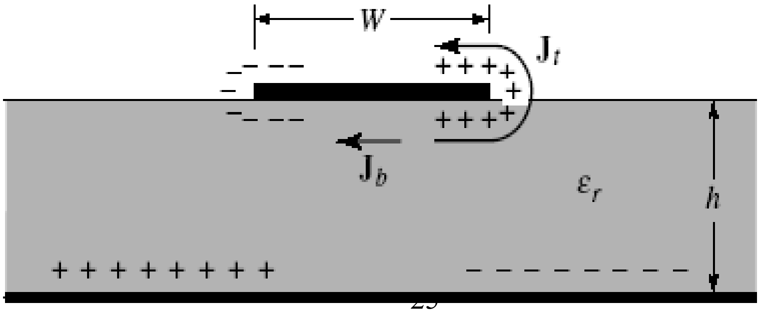


Fig2.14: Chargedistributionand current densitycreationon the microstrip patch

When the microstrip patch is provided power, a charge distribution is seen ontheupperandlowersurfacesofthepatchandatthebottomofthegroundplaneasshowninfigure-2.14thischargedistributioncontrolledbytwomechanisms-anattractivemechanisms and arepulsivemechanism.

Theattractivemechanismisbetweentheoppositechargesonthebottomsideof the patch and the ground plane, which helps in keeping the charge concentrationintact at the bottom surface of the patch, which causes pushing of some charges fromthebottom,tothetopofthepatch.thebottomofthepatch.Thepropulsivemechanism is between the like charges. As a result of this charge movement, currentsflowat thetop and bottom surfaceof thepatch

The cavity model assumes that the height to width ratio(i.e. the height of thesubstrate and width of the patch) is very small and as a result of this the attractivemechanism dominates and causes most of the charge concentration and the current tobe below of the patch surface. Much less current would flow on the top surface of theratio further decreases, the current on the top surface will be almost equal to zero,whichwouldnotallowthecreationofanytangentialmagneticfieldcomponentstothepatchedges.Hence,foursidewallscouldbemodeledasperfectlymagneticconductingsurfaces.

Thisimpliesthatthemagneticfieldsandtheelectricfielddistributionbeneath the patch would not be disturbed. However, in practice, a finite width toheight ratio would be there and this would not make the tangential magnetic fields tobe completely zero, but they being very small, the side walls could be approximatelytobe perfectlymagneticconducting.

Since the wall of the cavity, as well as the material within it, is lossless, thecavity would not radiate and its input impedance would be purely reactive. Hence, inorder to account for radiation and a loss mechanism, one must introduce a radiationresistanceR_R and aloss resistanceR_L.

2.7CircularlyPolarizedMicrostripPatchAntennas:

2.7.1 TypesofCircularlyPolarizedmicrostripPatchantenna:

Amicrostrippatchisoneofthemostwidelyusedradiatorsforcircularpolarization. Figure2.15 shows some patches, including square, circular, equilateraltriangular,ring,andellipticalshapeswhicharecapableofcircularpolarizationoperation. However, square and circular patches are widely utilized in practice. Asingle patch antenna can be made to radiate circular polarization if two orthogonalpatch modes are simultaneously excited with equal amplitude and90out of phasewithsigndeterminingthesenseofrotation.Twotypesoffeedingschemescanaccomplish in the task. The first type is dual-orthogonal food, which employs anexternal power divider network. The other is a single point for which an externalpowerdivideris not required

2.7.1.1 Dual-Orthogonal Fed circularly Polarized microstrip Patchantenna:

The patch is usually square or circular. The dual-orthogonal feeds excite twoorthogonalmodeswithequalamplitudebutin-Phasequadrature.Severalpowerdivider circuits that have been successfully employed for CP generation include thequadrature hybrid, the ring hybrid, the Wilkinson power divider, and the Functionpower splitter. The quadrature hybrid splits the input into two outputs with an equalmagnitude but 90°out of phase. However, breed a quarter wavelength line in one oftheoutput arms to producea90°phaseshift atthetwo feeds.

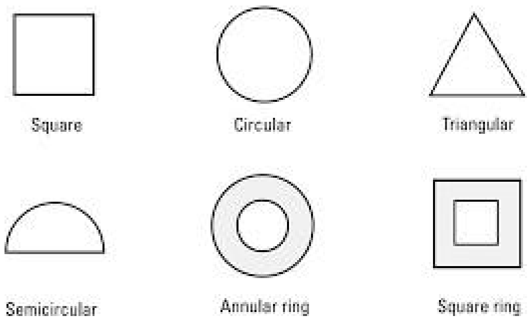
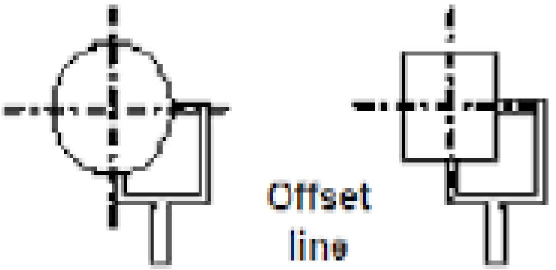


Fig2.15:Various typesofcircularlypolarizedmicrostrippatch antennas



(a) (b)

Fig 2.16: Typical configurations of dual-fed circularly Polarized microstripAntennas: a) circular patch(b)squarepatch

2.7.1.2 SinglyFedCircularlyPolarizedmicrostripPatchantenna:

Typical configurations for a singly fed CP microstrip antenna are shown in thesheet. A single point feed patch capable of producing CP radiation is very desirable insituations where it is difficult to accommodate dual-orthogonal feeds with a powerdividernetwork.

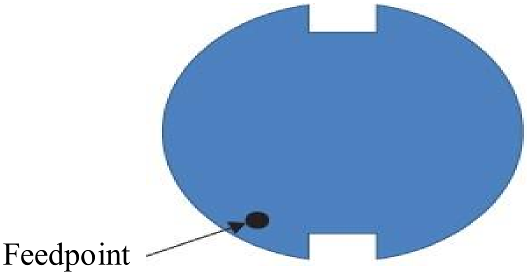


Fig 2.17: Typical configurations of singly fed circularly polarizedmicrostripantenna(a)CircularPatch

Becauseapatchwithsingle-pointfeedgenerallyradiateslinearpolarization,in order to radiate CP, it is necessary for two orthogonal patch modes with equalamplitudeanin-phasequadraturetobeinduced.Perturbationconfigurationsforgenerating CO operate on the principleo detuning Degenerate modes of the syndicalpatch by perturbation some shown in figure 2.17. The fields of a singly fed patch canbe resolved orthogonal degenerate modes and. Proper perturbation sets will detunefrequency response of mode 2 such that at the opening frequency of the axial ratiorapidlydegrades whiletheinput match remains acceptable.

Circular polarization can alsobe obtained froma single-point-fed square ofthe circular patch on normally biased ferrite substrate, as shown in figure 2.17. Polardemonstratedthatasinglyfedpatchradiatesbothlefthandcircularlypolarized(LHCP) and right and circularly polarized(RHCP) at the same level andpolarity of bias magnetic field however LHCP and RHCP have different resonantfrequencies. At the same operating frequency, the polarization can be reversed byreversing the polarity of the bias field. The axial ratio bandwidth is found to be largerthan theimpedancebandwidth. Theradiation efficiencyis 70%.

Dual circular polarization has also been achieved using a singly fed triangular orPentagonal microstrip antenna. A triangular patch radiates CP at dual frequencies, f1and f2, with the separation ratio depending on the aspect ratio b/a. RHCP can bechangedtoLHCPateachfrequencybymovingthefeedlocationintoΓ2fromΓ4to Γ3The aspect ratio b/a is generally very close to unity, hence, a triangular patch isalmost equilateral. Apentagonal patch in figure 2.17, with the aspect ratio c/an as adesign parameter, also behaves in a similar manner, It radiates RHC when the feedpoint.

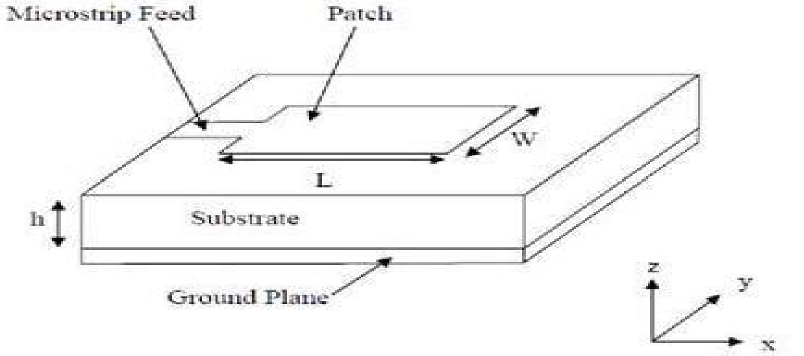


Fig2.18: Geometryofarectangle patch antennaon anormallybiasedsubstrate

2.8 AdvantagesandDisadvantage:

Microstrippatchantennasareincreasinginpopularityforuseinwirelessapplications duetotheirlow-profilestructure.Thereforetheyareextremelycompatible with embedded antennas in handheld wireless devices such as cellularphones,pagers,etc.Thetelemetryandcommunicationantennasonmissilesneedtobe thin and conformal and are often in the form of Microstrip patch antennas. Anotherarea wheretheyhavebeen used successfullyis inSatellite communication.

- Lightweightandlowvolume
- Lowprofileplanarconfigurationwhichcanbeeasilymadeconformaltohostsurface
- LowFabricationcost,hencecanbemanufacturedinlargequantities
- Supportsboth,linearaswellascircularpolarization.
- Itcanbe easilyintegratedwithmicrowaveintegratedcircuits(MIC).
- Capableofdualandtriplefrequencyoperations

- Mechanicallyrobustwhen mountedon rigidsurfaces
- Microstrippatchantennassufferfrommoredrawbacksascomparedtoconventional antennas

Someoftheirmajordisadvantagesare givenbelow:

- Narrowbandwidth
- Low efficiency
- LowGain
- Extraneousradiationfrom foodsandjunctions
- Poorend-fire radiator exceptfortaperedslot antennas
- Lowpowerhandlingcapacity
- Surfacewaveexcitation

Microstrippatchantennashaveaveryhighantennaqualityfactor(Q).Itrepresents the losses associated with the antenna where a large O leads to narrowbandwidth and low efficiency. Q can be reduced by increasing the thickness of thedielectric substrate. But as the thickness increases, an increasing fraction of the totalpowerdeliveredbythesourcegoesintoasurfacewave.Thissurfacewavecontribution can be counted as an unwanted power loss since it is ultimately scatteredat the dielectric bends and causes degradation of the antenna characteristics. Otherproblems such as lower gain and lower power handling capacity can be overcome byusinganarrayconfiguration for theelements.

2.9 Applications:

Microstripantennahasfoundapplicationsintelemetry,satellitecommunication,and variousmilitary radarsystems.Openinginthe1to10GHzfrequency range.Itismainly duetoadvantageslikelowprofileandcaseoratintegratingthemicrostripantennawiththesolid-statereceivingortransmittingmodule opens up the possibility of building large antenna array system with eachelementbeinganactiveindividually controlledelementapplicationofmicrostripantennais tabulated below

Table2.1:VariousapplicationsofMicrostripantenna

Aircraft	Radarcommunications, Navigationlandingsystem
Missiles	Radar, Telemetry
Satellites	Communicationdirect broadcastTV
Ships	Radarcommunication navigation

2.9.1 Mobileandsatellitecommunicationapplication:

Mobile communication requires small low-cost low profile antennas. Microstrippatch antenna meets all Requirements and various types of microstrip antennas havebeen designedfor use in mobile communication systems.In the case of satellitecommunication,circularlypolarizedradiationpatternsarerequiredandcanberealizedusingeither asquareorcircular patch with one ortwo feed points.

2.9.2 GlobalPositioningSystemapplications:

Nowadays microstrip patch antennas with a substrate having high permittivitysinteredmaterialareusedfortheglobalpositioningsystem.Thisantennasurecircularly polarized very compact and quite expensive due to its positioning. It isexpectedthatmillionsofGPSreceiverswillbeusedbythegeneralpopulationforlandvehicleaircraft andmaritimevessels to find thereposition accurately

2.9.3 RadioFrequencyIdentification(RFID):

RFID in different areas like mobile communication, logistics, manufacturing,transportation, andhealthcareRFIDsystemsongsfrequencies between 30Hzand5.8

GHzdependingonitsapplicationsRFIDsystemisatagortransponderandatransceiver.

2.9.4 WorldwideInteroperabilityforMicrowaveAccess(WiMax):

The IEEE 802.16 Standard is known as WiMax. It can reach up to a 30-mileradius theoretically anddata rate 70Mbps. MPA generates three resonant modesat2.7,3.3und5.3GHz,andcan,therefore,beusedinWiMaxcompliantcommunicationequipment.RadarApplication:Radargunisusedfordetectingmoving targets such as people and vehicles. It demands a low profile, lightweightantennasubsystem,themicrostripantennasareanidealchoice.Thefabricationtechnologybasedonphotolithographyenablesthebulkproductionofmicrostripantenna with a repeatable performance at a lower cost ina lesser time frame ascomparedtotheconventionalantennas.RectennaApplication:Rectennaisarectifyingantenna,aspecialtypeofantennathatisusedtodirectlyconvertmicrowave energy into DC power. Rectenna is a combination of four subsystems Le.Antenna, ore rectification filter, Rectifier, post rectification filter. In the rectennaapplication,itisnecessarytodesignanantennawithveryhighdirectivecharacteristics to meet the demands of long-distance links. Since the aim is to use therectenna to transfer DC power through wireless links for a long distance, this can onlybeaccomplished byincreasingtheelectrical sizeof theantenna.

2.9.5 TelemedicineApplication:

In the telemedicine application antenna is operating at 2.45 GHz. WearablemicrostripantennaissuitableforWirelessBodyAreaNetwork(WBAN).Theproposed antenna achieved a higher gain and front to back ratio compared to the otherantennas, in addition to the semi-directional radiation pattern which is referredoverthe omnidirectional pattern to overcome unnecessary radiation to the user's body andsatisfies the requirement for on-body and off-body applications. An antenna having again of 6.7 dB and an F/B ratio of 11.7 dB and resonates at 2.45GHz is suitable forTelemedicine applications

2.9.6 MedicinalApplication:

It is found that in the treatment of malignant tumors the microwave energy issaidtobethemosteffectivewayofinducinghyperthermia.Thedesignoftheparticular radiator which is to be used for this purpose lightweight, easy in handling,and to be rugged. Only the path radiator fulfills these requirements. The initial designsfortheMicrostripradiatorforinducinghyperthermiawerebasedontheprinteddipole s and annular rings which were designed on S-band. And later on, the designwas based on the circular microstrip disk at L-band. There is a simple operation thatgoesonwiththeinstrument;twocoupledMicrostriplinesareseparatedwithaflexibleseparationwhichisusedto measurethetemperatureinsidethehuman body.

3 Ultra-Wideband Antenna

3.1INTRODUCTION:

Ultra-wideband also is known as UWB, ultra-wideband, and the ultra band is a radio technology that can use a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating, and tracking applications. Unlike the spread spectrum, UWB transmits in a manner that does not interfere with conventional narrowband and carrier wave transmission in the same frequency band.

Ultra-Wideband (UWB) communication systems have the promise of very high bandwidth, reduced fading from multipath, and low power requirements. For our project, we designed a UWB antenna for a handheld communications device with a bandwidth of 225 to 400 MHz, a voltage standing wave ratio (VSWR) of less than 1.5 to 1, and an efficiency of greater than 75 percent. The antenna had to be resistant to body effects, which means that if the communications unit is put up to the user's head or put on a large metal surface, that the radiation pattern will not be greatly affected. Our antenna also had to be small enough to fit on the communication device, which was ten inches high, by three inches wide, by one inch thick.

Ultra-wideband is a technology for transmitting information spread over a large bandwidth (>500 MHz): this should, in theory, and under the right circumstances, be able to share spectrum with other users. Regulatory settings by the Federal Communications Commission (FCC) in the United States intend to provide efficient use of radio bandwidth while enabling high-data-rate personal area network (PAN) wireless connectivity, long-range, low-data-rate applications, and radar and imaging systems.

Ultra-wideband was formerly known as pulse radio, but the FCC and the International Telecommunication Union Radio communication Sector (ITU-R) currently define UWB as an antenna transmission for which emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the arithmetic center frequency. Thus, pulse-based systems-where each transmitted pulse occupies theUWB bandwidth (or an aggregate of at least 500 MHz of the narrow-bandcarrier; for example, orthogonal frequency-division multiplexing (OFDM) canaccess the rules. Pulse repetition rates may be either low or very high. Pulse-basedUWBspectrumunderradarsandimagingsystemstendtouselowrepetition rates (typically in the range of 1 to 100 mega pulses per second). Ontheotherhand,communicationssystemsfavorhighrepetitionrates(typicallyinthe range of one to two Giga pulses per second), thus enabling short-rangegigabit-per-second communications systems. Each pulse in a pulse-based UWBsystemoccupiesthe entire UWB bandwidth.ThisallowsUWB toreapthebenefits of relative immunity to multipath fading, unlike carrier-based systemswhich are subject to deep fading and inter-symbol interference. However, bothsystemsaresusceptible to inter symbol interference.

A significant difference between conventional radio transmissions andUWB is that conventional systems transmit information by varying the powerlevel,frequency,and/orphaseofasinusoidalwave.UWBtransmissionstransmit information by generating radio energy at specific time intervals andoccupying largebandwidth,thusenabling pulse-positionortimemodulation.The informationcan also be modulated on UWB signals (pulses)by encodingthe polarity of the pulse, its amplitude, and/or by using orthogonal pulses. UWBpulses can be sent sporadically at relatively low pulse rates to support time orposition modulation, but can also be sent at rates up to the inverse of the UWBpulse bandwidth. Pulse-UWB systems have been demonstrated at channel pulsesrates in excess of 1.3 Giga pulses per second using a continuous stream of UWBpulses(ContinuousPulseUWBorC-UWB),supportingforwarderrorcorrectionencoded data rates in excess of 675Mbit/s.

A valuableaspectof UWB technology is the ability of aUWB radiosystemtodeterminethetimeofflight"ofthetransmissionatvariousfrequencies. This helps overcome multipath propagation, as at least some of thefrequencies have a line-of-sight trajectory. With a cooperative symmetric two-waymeteringtechnique,distancescanbemeasuredtohighresolutionandaccuracybycompensatingfor local clock drift andstochasticinaccuracy.

Another feature of pulse-based UWB is that the pulses are very short (lessthan 60 cm for a 500 MHz-wide pulse, less than 23 cm for a 1.3 GHz-bandwidthpulse) so most signal reflections do not overlap the original pulse, and there is nomultipathfadingofnarrowbandsignals.However,thereisstillmultipathpropagation and inter-pulse interference to fast-pulse systems, which must bemitigated bycodingtechniques.

3.2HistoryandBackground:

The term "Ultra-wideband" has several similar meanings such as impulse,carrier-free baseband, and large relative bandwidth radio or radar signals. Theconcept of Ultra-wideband technology is not new. The first pulse-based UWBspark Gap radio was developed by Guglielmo Marconi in late 1800 which wasused to transmit Morse Code for several years. However, in early 1900, theseradioswereforbiddentouseinmanyapplicationsduetotheirstrongpoweremissionandinterferencewithothernarrowbandradiosystems,whichweredeveloped in the early1900s.

In the late 1960s, UWB technology gained a lot of interest because of itsuse in the form of impulse radar in the military areas. During this era, significantresearch efforts were conducted by researchers on different aspects of Ultra-Wideband technology.In 1964 Hewlett Packard and TektronixInc. producedthe first time domain instruments for sub-nanosecond pulse diagnostics whichwas a huge step in UWB system design. Antennas designers such as Ramsey,Dyson, and Ross have started the design of antennas for UWB systems. RumseyandDysondevelopedlogarithmicspiralantennasandRossusedimpulsemeasurement techniques for the design of wideband radiating antenna elements.During 1960 to 1999, nearly a 40 year period, over 200 papers were published inaccredited IEEE journals, and more than 100 patents were ed on topics related toUWB technology for radar and communication became Mainly, in the mid-1980s, the FCC allocated the Industrial Scientific and Medicine (ISM) bands forunlicensed wideband communication use. Owing to this revolutionary spectrumallocation, WLAN and Wireless Fidelity (Wi-Fi) have gone through tremendousgrowth.Italsoleadsthecommunicationindustrytostudythemeritsandimplicationsof wide bandwidth communication.

At the beginning of 2002, UWB was reborn after FCC approved the UWBtechnology for commercial use. UWB systemshave a number of advantagesover traditional narrowband systems which makes it suitable for a variety ofapplicationsincludingradarmeasurementsinthetimedomainresolution.Attributessuchaslowpowerconsumption,negligibleinterferencetonarrowbandsystemsinherentimmunityyagainstdetectionandinterception,strongpenetrationabilitythroughdifferentmaterials,etcmakesUWBtechnologyagoodcandidateforthrough-the-wallandgroundpenetratingapplications. This short-range, high-throughput wireless technology can transmitwith data rates of 252Mbps, and a data rate of 480Mbps is expected to beachievedin thenearfuture.

3.3BANDASSIGNMENT:

TheUWBbandcoversafrequencyspectrumof7.5GHz.i.e.from3.1GHz to 10.6 GHz. Such a wide band can be utilized with two differentapproaches:

1.Single-bandscheme

2. Multibandscheme.

Information can be encoded in a UWB signal in various methods. Themostpopularsignalmodulationschemesfor UWBsystemsincludepulse-amplitude modulation (PAM), pulse-position modulation (PPM), binary phase-shiftkeying(BPSK), andso on.

UWBsystemsbasedonimpulseradioaresingle-bandsystems.Theytransmit short pulses which are designed to have a spectrum covering the entireUWB band. Data is normally modulated using the PPM method and multipleusers can besupportedusingthe time-hoppingscheme.

Generallyineachframe,therewillbeacertainnumberoftimeslotsallocated to some users; for each user, the UWB signal is transmitted at onespecificslot which determined byapseudo-random sequence.

The other approach to UWB allocationisa multi-band schemewherethe7.5GHz UWB band is divided into several smaller sub-bands. Each sub-bandhas a bandwidth no less than 500MHz so as to conform to the FCC definition oftheUWBmulti-bandscheme,multipleaccesscanbeachievedbyusingfrequency hopping. Here the UWB signal is transmitted over some sub-bands ina sequence during the hoping period and it hops from frequency to frequency atfixed intervals. At any time, only one sub-band is active for transmission whiletheso-calledtime-frequencyhoppingcodesareexploitedtodeterminethesequencein which thesub-bands areused.

Single-band andmulti-bandUWBsystemspresentdifferent features.

For a single-band scheme, the transmitted pulse has an extremely shortduration, so a very fast switching circuit is required. On the other hand, themulti-band systems need a signal generator which is able to quickly switchbetweenfrequencies.

Single-band systems can achieve better multipath resolution compared tomultiband systems because they employ discontinuous transmission of shortpulses and normally the pulse duration is shorter than the multipath delay.Whilemultiband systems may benefit from the frequency diversity across sub-bands toimprovesystem performance.

Besides, multiband systems can provide good interference robustnessand coexistence properties. Forexample, when the system detects thepresenceof the wireless systems, it can avoid the use of the sub-bands which share thespectrumwith thosesystems.

BelowFigure 3.1 presentsan exampleof a time-hopping scheme.Eachframe,areeight-timeslotsallocatedtoeightusers,foreachuser theUWBsignal

istransmitter at onespecificslotwhichdeterminedbyapseudo-randomsequence.

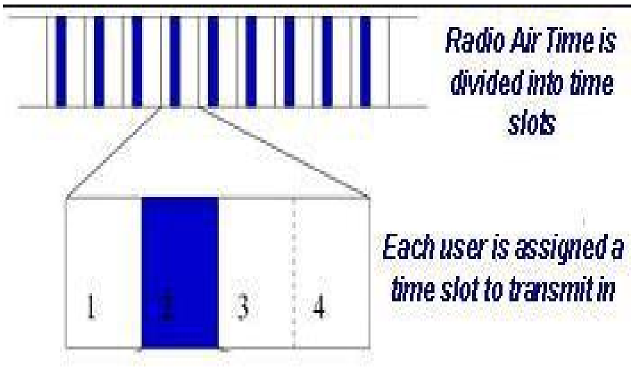


Fig3.1:Time hoppingconcept

other approach to UWB spectrum allocation is a multi-band schemewhere the 7.5GHz UWB band is divided into several smaller sub-bands. Eachsub-band has a bandwidth no less than 500MHz so as to conform to the FCCdefinitionofUWB.

Inamulti-bandscheme,multipleaccesscanbeachievedbyusingfrequency hopping. As exemplified in Figure 3.2, the UWB signal is transmittedover eight sub-bands in a sequence during the hopping period and it hops fromfrequency to frequency at fixed intervals. At any time, only one sub-band isactive for transmission while the so-called time-frequency hopping codes areexploitedto determinethe sequencein which thesub-bands areused.

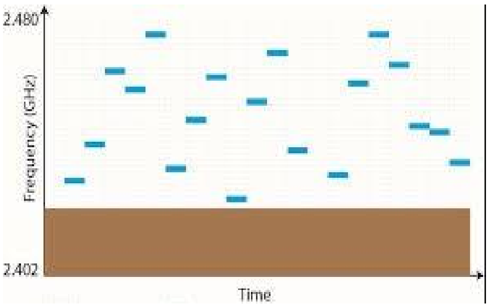


Fig 3.2 frequency hopping concept

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To achieve the same result, a single-band system would need to exploitnotch filters. However, this may increase the system complexity and distort thereceivedsignal waveform.

3.4 CHARACTERISTICSOFUWB:

UWB technology can do things that the existing wireless networkingsystems cannot. Most importantly, UWB can handle more bandwidth-intensiveapplications like streaming video, than faster rates. UWB technology has a datarate of roughly 100 megabits per second for 802.11b (often referred to as Wi-Fi)which is the technology currently used in most wireless Lan's; and 54 megabitsper second for 802.11a, which is Wi-Fi at 5MHZ. either 802.11 or Bluetoothbecause it can send data at much Bluetooth hasa data rate of about 1 megabitpersecond.

3.4.1 LowPowerConsumption:

While transmitting data, UWB devices consume less than several tens ofmicrowatts. This is a huge saving and the reason is that UWB transmits shortimpulses constantly instead of transmitting modulating waves continuously asmost narrowband systems do. UWB chipsets do not require Radio Frequency(RF) 10 Intermediate Frequency (IF) conversion, Local Oscillators, mixers, andother filters. The low power consumption makes UWB ideal for use in battery-powereddevices likecameras andcellphones.

3.4.2 InterferenceImmunity:

Due to low power and high-frequency transmission, UWB's aggregateinterference is “undetected” by narrowband receivers. Its power spectral densityis at or below the narrowband thermal noise floor. The low power level thuscreates no irritating interferences to existing home wireless systems. AccordingtoitsFirstReportandOrder,theFCCrequiresthatindoorUWBdevices transmit only when operating with a receiver. A device connected to AC poweris not constrained to reduce or conserve power by ceasing transmission, so thisrestriction will eliminate unnecessary emissions. Additional tests conducted bytheFCChavealsodemonstratedconclusivelythatUWBdevicesmaybepermitted to operate under a proper set of standards without causing harmfulinterferenceto other operations.

3.4.3 HighSecurity:

UWB'S white-noise like transmissions enhance security since receiverswithoutthespecificcodecannotdecodeit.Differentcodingschemes,algorithms,and modulation techniquescan be assigned todifferent users fordata transmissions. Security can also be realized at the Media Access Control(MAC)levelbyallowingtwodevicestocommunicatewitheachother.Although currently, no formal security standard is available for UWB, the studygroupIEEE802.15.3hasdefinedAES-128symmetricsecurityforpayloadprotectionand integrity.

3.4.4 Reasonablerange:

IEEE 802.15.3a Study Group defined 10 meters as the minimum range atspeed 100Mbps. However, UWB can go further. The Philips Company has usedits Digital light processor (DLP) technology in the UWB device soit canoperatebeyond 45 feet at50Mbpsforfour DVDscreens.

3.4.5 LowComplexity,LowCost:

The most attractive of UWB advantages are of low system complexity andcost. Traditional carrier-based technologies modulate and demodulate complexanalog carrier waveforms. In contrast, UWB systems are made of "all-digital"with minimal RF or microwave electronics. The inherent RF simplicity in UWBdesign makes the systems highly frequency adaptive and enables them to bepositionedanywherewithintheRFspectrum.Also,homeUWBwirelessdevicesdonotneed transmittingpoweramplifiers.Thisisagreatadvantageover narrowband architectures that require amplifiers with significant powerback-off to support high-order modulation waveforms for high data rates. Thecost of placing UWB technology inside a consumer electronics device is $20,comparedwith $40 for 802.11b and $65 for802.11a.

3.5 AdvantagesofUWB:

UWB has a number of encouraging advantages that are the reasons why itpresentsamoreeloquentsolutiontowirelessbroadbandthanothertechnologies.

Firstly, according to the Shannon-Hartley theorem, channel capacity is inproportion to bandwidth. Since UWB has an ultra-wide frequency bandwidth, itcan achieve huge capacity as high as hundreds of Mbps or even several Gbpswithdistances ofIto 10meters.

Secondly,UWB systemsoperate atextremely lowpower transmissionlevels. By dividing thepower of the signal across a hugefrequency spectrum,the effect upon any frequency is below the acceptable noise floor, as illustratedin Figure3.

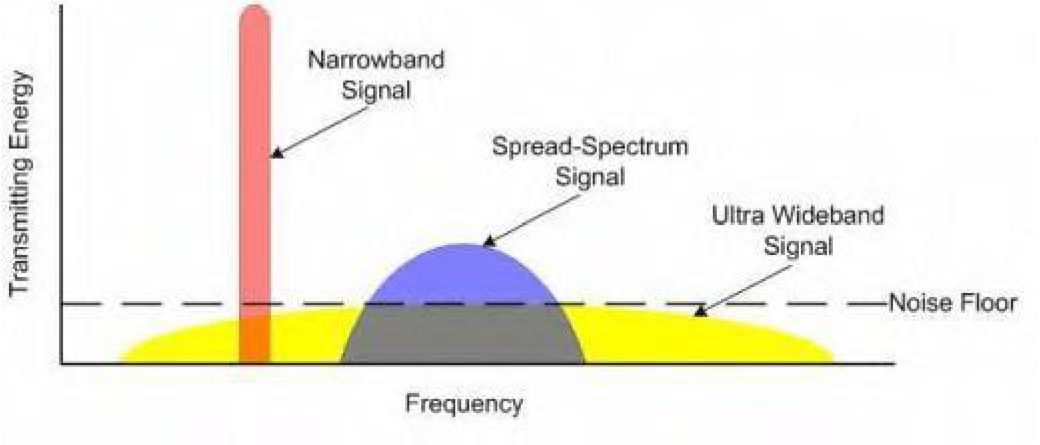


Fig3.3:Ultra-widebandcommunicationsspreadtransmittingenergyacrosswide spectrum offrequency.

For example, 1 watt of power spread across MHZ of spectrum results inonly 1 nanowatt of power into each hertz band of frequency. Thus, UWB signalsdonot cause significantinterferenceto otherwireless systems.

Thirdly, UWB provides highly secure and high reliable communicationsolutions. Due to the low energy density, the UWB signal is noise-like, whichmakes unintended detection quite difficult. Furthermore, the noise-like" signalhas a particular shape, contrast, real noise has no shape. For this reason, it isalmost impossible for real noise to obliterate the pulse because interferencewould have to spread uniformly across the entire spectrum to obscure the pulse.Interferenceisonlypartofthespectrumreducestheamountofreceivedsignal,butthepulsestillcanberecoveredtorestorethesignal.HenceUWBisperhapsthemost securemeansofwireless transmissionever previouslyavailable.

Lastly, the UWB system based on impulse radio features low cost and lowcomplexitywhicharisefromtheessentialbasebandnatureofthesignaltransmission.UWB doesnotmodulateanddemodulateacomplexcarrierwaveform, so it does not require components such as mixers, filters, amplifiers,andlocal oscillators.

3.6 UWBStandards:

A standard is a precondition for any technology to grow and developbecause it makes possible the wide acceptance and dissemination of productsfrom multiple manufacturers with an economy of scale that reduces costs toconsumers.Conformancetostandardsmakesitpossiblefordifferentmanufacturers to create products that are compatible or interchangeable witheachother.

InUWBmatters,theIEEEisactiveinmakingstandards.TheIEEE802.15.4ataskgroupis focusedonlowratealternativephysicallayerforWPANs. The technical requirements for 802.15.4a include low cost, low datarate(>250kbps), low complexity,and low powerconsumption.

TheIEEE802.15.3ataskgroupisaimedatdevelopinghighratealternativephysicallayer forWPAN.802.15.3aisproposedtosupportadatarate of 110Mbps with a distance of 10 meters. When the distance is furtherreducedto4metersand2meters,thedataratewillbeincreasedto200Mbpsand480Mbps ,respectively.Therearetwocompetingproposalsfor802.15.3a,

i.e.theDirectSequenceUWB(DS-UWB)andtheMultibandOrthogonalFrequencyDivision Multiplexing(MBOFDM).

DS-UWB proposal is the conventional impulse radio approach to UWBcommunication, i.e. it exploits short pulses that occupy a single band of severalGHzfor transmission. Thisproposalismainly backedby a Free scale andJapanese NICT and its proponents have established their own umbrella group,namely,theUWBForum.

DS-UWBproposalemploysdirectsequencespreadingofbinarydatasequencesfortransmission modulation.

The concept of direct sequence spread spectrum (DSSS) is illustrated inFigure 3. 4.Theinputdatais modulatedbyapseudo-noise (PN) sequencewhich

is a binary sequence that appears random but can be reproduced at the receiver.Each user is assigned a unique PN code which is approximately orthogonal tothose of other users. The receiver can separate each user based on their PN codeeveniftheysharethesamefrequencyband.Therefore,manyuserscansimultaneouslyusethesamebandwidthwithoutsignificantlyinterferingwithoneanother.

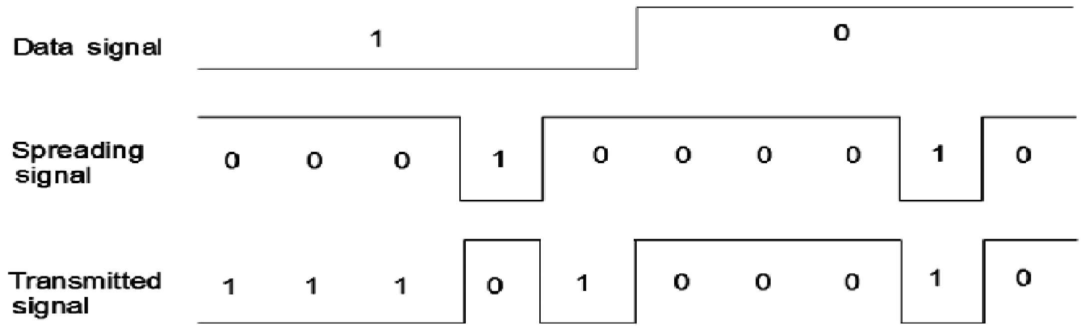


Fig3.4:Exampleof Directsequencespreadspectrum

Thedifferentachievabledataratesareobtainedbyvaryingtheconvolutioncoderateand thespreadingcodelength.Thecodelengthdetermines the number of chips duration used to represent one symbol. Hence, ashorter code length will lead to a higher data rate for a fixed error-correctingcoderate.

The main advantage of DS-UWB is its immunity to the multipath fadingdue to the large frequency bandwidth. It is also flexible to adapt very high datarates in averyshort distance

However, there is also a technical challenge to DS-UWB. As shown inTable, the FCC defined a single band of 7.5GHz for UWB communications, butthis3.1GHz 10.6GHz band is broken down into low and high sub-bands. Thus, anefficient pulse shaping filter is required in order to comply with the variousspectralmasks proposedbydifferentregulatorybodies.

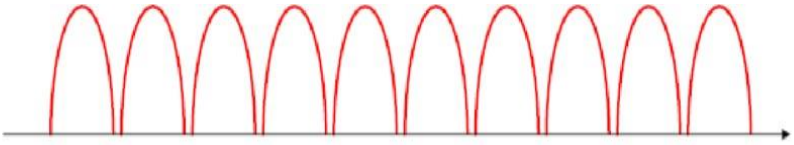
Table 3.1:ProposedUWBband intheworld

Region	UWBband
UnitedStates	SingleBand: 3.1GHz-10.6GHz

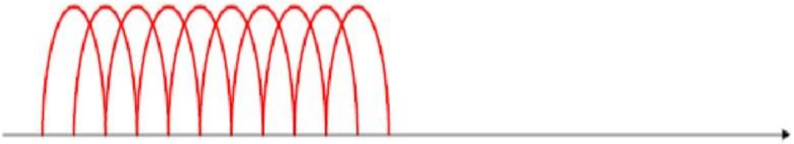
Europe	Low Band:3.1GHz-4.8GHz High Band:6GHz-8.5GHz
Japan	Low Band:3.4GHz-4.8GHz HighBand:7.25GHz-10.25GHz

MB-OFDMproposalissupportedbyMulti-BandOFDMAlliance(MBOA)whichiscomprisedofmorethan100companies.MB-OFDMcombinesthemultibandapproachtogetherwiththeorthogonalfrequencydivisionmultiplexing(OFDM)techniques.

OFDM is a special case of multicarrier transmission, where a single datastream is transmitted over a number of lower rate sub-carriers. Because the sub-carriers are mathematically orthogonal, they can be arranged in an OFDM signalsuch that the sidebands of the individual sub-carriers overlap, and the signals arestill received without adjacent carrier interference. It is apparent that OFDM canachieve higher bandwidth efficiency compared with conventional multicarriertechnique,as shown in figure4



(a) FDM



(b) OFDM

Fig3.5:OFDMtechniqueversusconventionalmulticarrier technique

3.7UWBApplications:

Asmentionedearlierinthischapter,UWBofferssomeuniqueanddistinctiveproperties thatmakeit attractivefor variousapplications.

Firstly,UWBhasthepotentialforveryhighdataratesusingverylowpowerataverylimitedrange,whichwillleadtotheapplicationswellsuitedforWPAN.Theperipheralconnectivitythroughcablelessconnectionstoapplications like storage, 10 devices, and wireless USB will improve the easeandvalueofusingPersonalComputers(PCs)andlaptops.Highdataratetransmissions between computers and consumer electronics like digital cameras,video cameras, MP3 players, televisions, personal video recorders, automobiles,andDVDplayerswillprovideanewexperienceinhomeandpersonalentertainment.

Secondly,sensorsofalltypesalsoofferanopportunityforUWBtoflourish. Sensor networks are comprised of a large number of nodes within ageographical area. These nodes may be static, when applied for securing thehome, tracking and monitoring, or mobile, if equipped on soldiers, firemen,automobiles, or robots in military and emergency response situations. The keyrequirementsforsensornetworksincludelowcost,lowpower,andmulti-functionality which can be well met by using UWB technology. High data rateUWB systems are capable of gathering and disseminating or exchanging a vastquantityofsensorydatainatimelymanner.Thecostofinstallationandmaintenance can drop significantly by using UWB sensor networks due to beingdevoidofwires.Thismeritisespeciallyattractiveinmedicalapplicationsbecause a UWB sensor network frees the patient from being shackled by wiresand cables when extensive medical monitoring is required. In addition, with awireless solution, the coverage can be expanded more easily and made morereliable.

Thirdly,positioning,andtracking isanother uniqueproperty ofUWB.Because of the high data rate characteristic in a short-range, UWB provides anexcellent solution for an indoor location with a much higher degree of accuracythan a GPS. Furthermore, with an advanced tracking mechanism, the precisedetermination of the tracking of moving objects within an indoor environmentcan be achieved with an accuracy of several centimeters. UWB systems canoperate in complex situations to yield faster and more effective communicationbetween people. They can also be used to find people or objects in a variety ofsituations,suchascasualtiesinacollapsedbuildingafteranearthquake,children lost in the mall, injured tourists in a remote area,firefighters in aburningbuilding,and soon.

Lastly, UWB can also be applied to radar and imaging applications. It hasbeen used in military applications to locate enemy objects behind walls andaroundcomersonthebattlefield.Ithasalsofoundvalueincommercialuse,such as rescue work where a UWB radar could detect a person's breath beneaththe rubble, ormedical diagnostics whereX-raysystems maybe less desirable.

UWB short pulses allow for very accurate delay estimates, enabling highdefinitionradar.Basedonthehighrangingaccuracy,intelligentcollision-avoidance and cruise control systems can be envisioned. These systems can alsoimprove airbag deployment and adapt suspension braking systems depending onroadconditions.Besides,UWBvehicularradarisalsousedtodetectthelocationand movement of objects near avehicle.

3.8 MAINAPPLICATIONSOFUWB:

UWB can be used as a communication link in a sensor network. It canalso create a security bubble around a specific area to ensure security. It is thebestcandidateto supportavarietyofapplicationssuchas:

WBANAPPLICATIONS:

The applications of wireless body area network (WBAN) in a medicalenvironmentmayconsistofsensors.AnetworkofUWBsensorssuchaselectrocardiogram(ECG),oxygensaturationsensor(SpO2),andelectromyography(EMG)canbeusedtodevelopaproactiveandsmarthealthcaresystem.Thiscanbenefitthepatientinchronicconditionsandprovideslongterm healthmonitoring.

WPANAPPLICATIONS:

A wireless personal area network (WPAN) is a personal area network, anetworkforinterconnectingdevicescenteredonanindividualperson'sworkspace in which the connections are wireless. Wireless PAN is based on thestandard IEEE802.15 operatingat 3.1-10.6GHz.

Wi-Fi:

Wi-Fi uses radio waves for connection over distances up to around 91meters, usually in a local area network(LAN) environment. Wi-Fi can be usedtoconnectlocalareanetworks,toconnectcellphonestotheInternettodownload music and other multimedia, to allow PC multimedia content to bestream to the TV (Wireless Multimedia Adapter), and to connect video gamesconsoles to their networks (Nintendo Wi-Fi Connection). 5.15-5.35 GHz and5.725-5.825 GHz, areusedbyWi-Fi devices.

Ultra-wideband(UWB)technologyessentiallyenablesthefollowingwirelesscommunicationsystems:-Short-range(up to 10 m), higher data-rates (upto 1 Gbits/s) applications suchastheIEEE802.15.3a(WPAN)standard operatingat 3.1-10.6 GHz;-Long-range(upto100m),lowerdatarates(upto1Mbits/s),e.g.wirelesssensornetworks operatingat frequencies below 960MHz.

4. Design of Monopole Antenna for UWB Applications

4.1 Introduction:

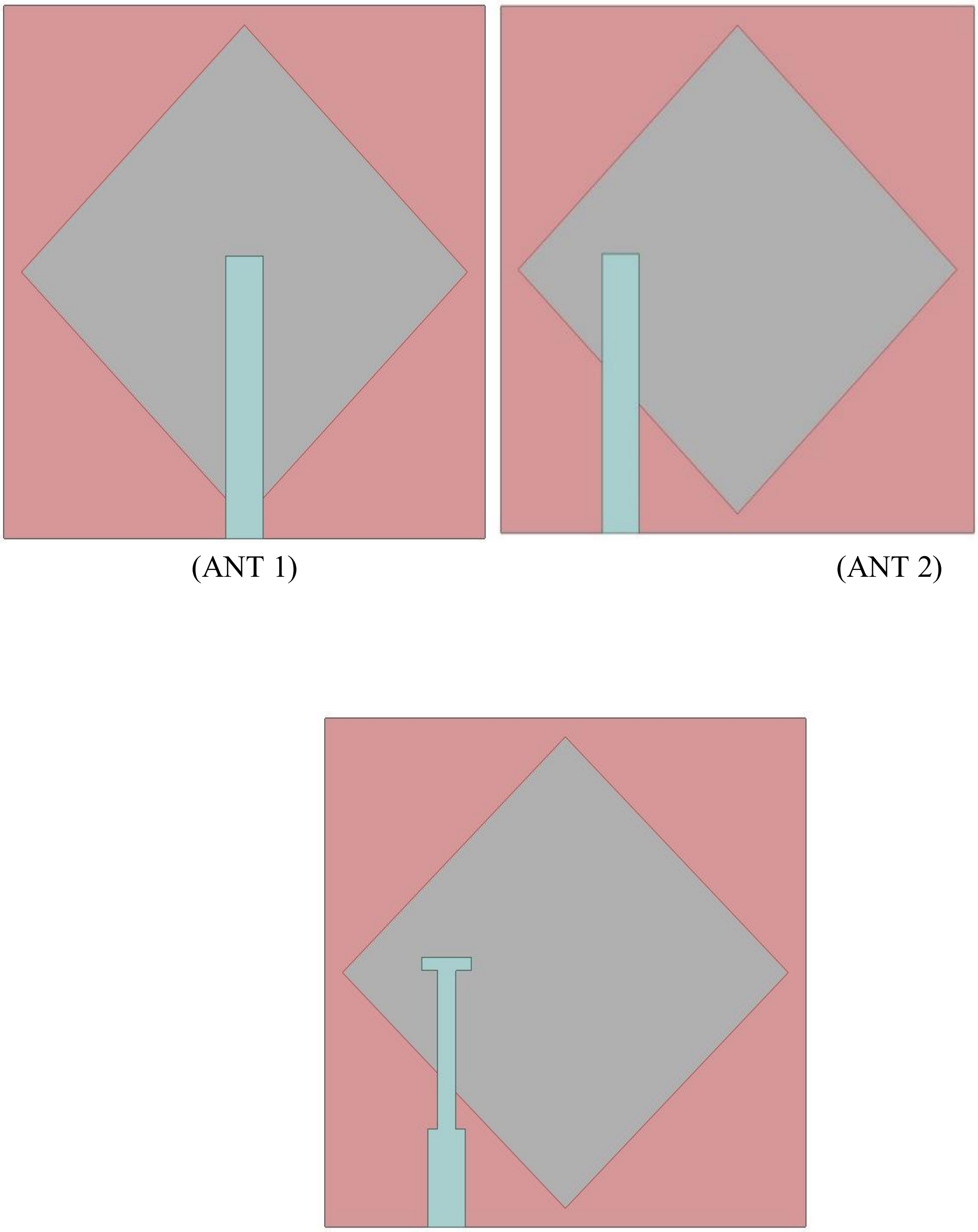
The UWB antenna should be consistent and predictable throughout the whole operation band. Examples include planarized and planar antennas. such as the Vivaldi antenna; volcano-smoke slot antennas; tulip-shaped monopole antennas; and many more. The tulip-shaped monopole antenna, for example, covers 2.55–32.5 GHz with fewer than -10 dB of reflection coefficient magnitude; hence, the operating band allocated by the FCC is entirely covered by this design. A few other designs also equal or approximate the FCC-allocated operating frequency band.

Some of the main features required for antennas for the application of UWB technology are as follows.

- It should have bandwidth ranging from 3.1 GHz to 10.6 GHz in which reasonable efficiency and satisfactory omnidirectional radiation patterns are necessary
- ultrawideband (UWB) techniques have drawn considerable attention due to the merits such as wide bandwidth, high data rate, and low cost.
- Although UWB communication system makes use of huge frequency bands, the permitted power spectral density of the UWB signal is rather limited to avoid interference with other systems

4.2 Design of UWB antenna element:

Fig.4.1 shows the design evolution of UWB antenna elements at different positions. Compared with the center-fed printed antenna with a rhombic slot (denoted as Ant. 1), good impedance matching over a wider frequency range can be achieved by adopting an offset microstrip-fed line (denoted as Ant. 2). This is due to the fact that the electromagnetic coupling between the feed line and the ground improves as the microstrip line is shifted from the center, and thereby enhances the impedance bandwidth of the antenna. The offset distance D1 has a significant influence on the impedance enhancement of the antenna element, and an optimum value D1 = 8 mm is selected in this design. The feed lines of Ant. 1 and 2 both have the same widths of 3 mm corresponding to 50-Ω characteristic impedance. Then a three-stage feed line is employed as an impedance transformer to adjust the impedance matching at 5-8 GHz (denoted as Ant. 3). Finally, an impedance bandwidth of larger than 3.1-10 GHz can be obtained to meet the bandwidth requirement for UWB operation.



(ANT 1)

(ANT 2)

(ANT 3)

Fig 4.1 (ANT 1) center-fed line, (ANT 2) offset microstrip-fed line,(ANT3) three-stagefeed line

4.3Results:

S11:

In this result, we simulate the antenna design at different positions. This is useful in selecting the desired position for the design.

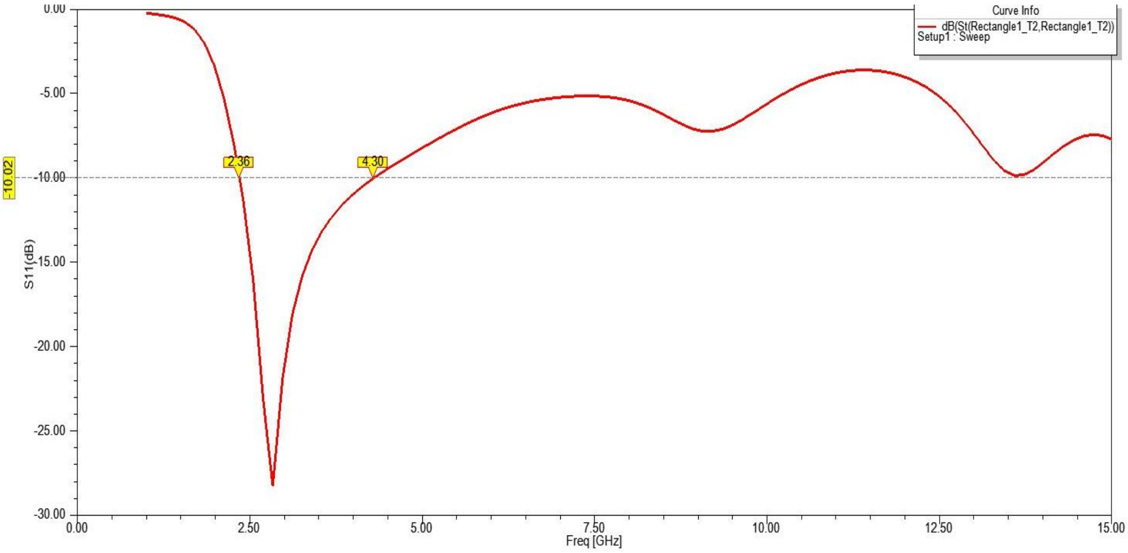


Fig 4.2: variation of return loss w.r.t frequency ofANT 1

From fig 4.2 we observed that center-fed printed antenna with a rhombic slot has very poor impedance matching over a wider frequency range.

S11

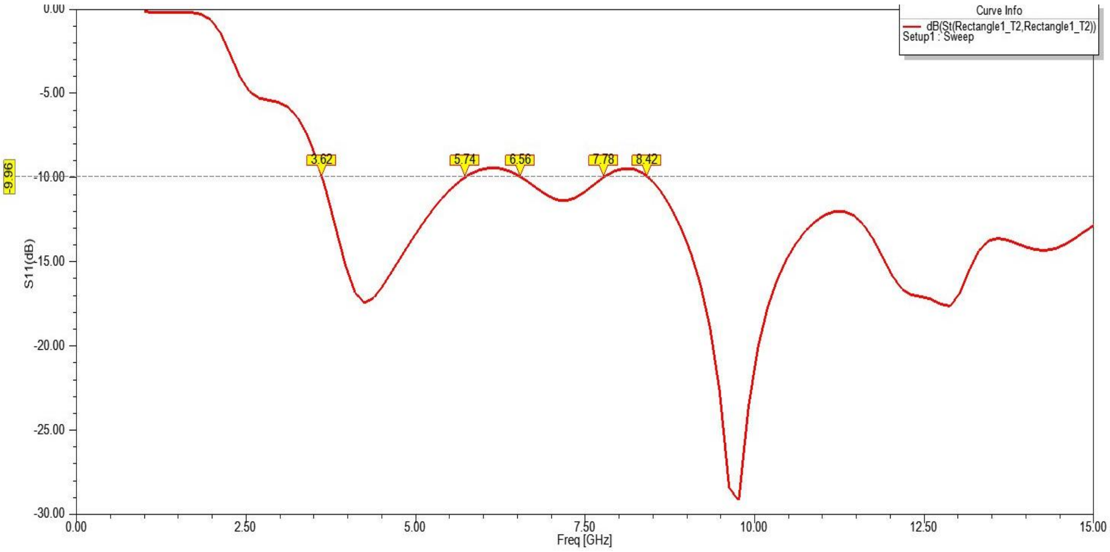


Fig 4.3: variation of return loss w.r.t frequency of ANT 2

From fig 4.3 we observed that compared with the centre-fed printed antenna with a rhombic slot (denoted as Ant. 1), good impedance matching over a wider frequency range can be achieved by adopting an offset microstrip-fed line (denoted as Ant. 2). This is due to the fact that the electromagnetic coupling between the feed line and the ground improves as the microstrip line is shifted from the centre, and thereby enhances the impedance bandwidth of the antenna.

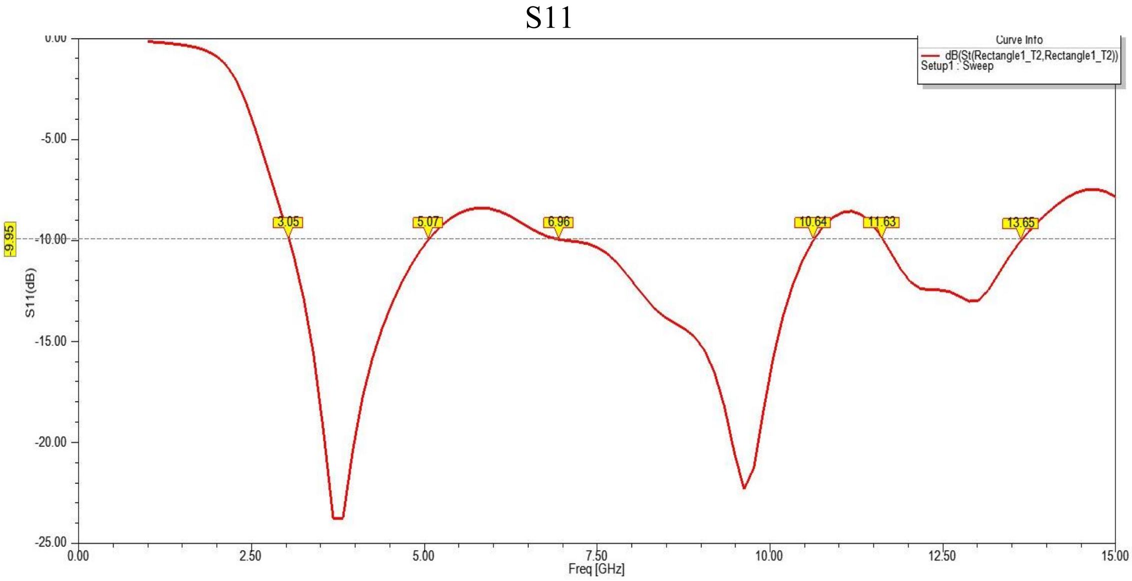


Fig 4.4: variation of return loss w.r.t frequency of ANT 3

From fig 4.4 a three-stage feed line is employed as an impedance transformer to adjust the impedance matching at 5-8 GHz (denoted as Ant. 3).

VSWR:

VSWR stands for Voltage Standing Wave Ratio and is also referred to as the Standing Wave Ratio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna and is the ratio of the maximum to minimum voltage transmitted by the antenna.

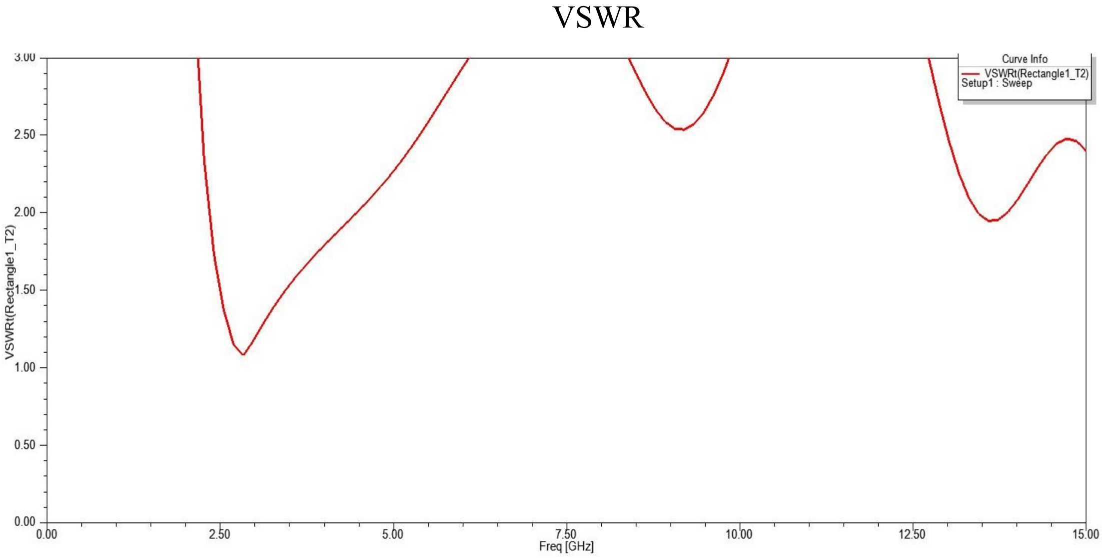


Fig 4.5: Variation of VSWR w.r.t frequency for ANT1

Fig:4.5 shows the simulated result of VSWR.For practical applications VSWR<=2 is acceptable. Here we can observe that some of the band is not less than or equal to 2.

VSWR

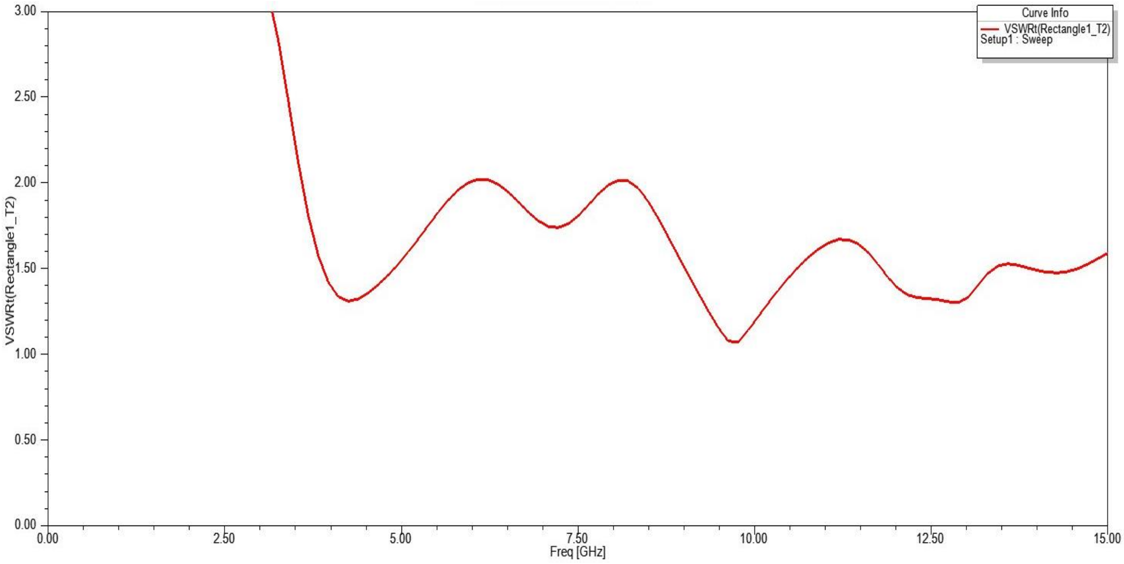


Fig 4.6: Variation of VSWR w.r.t frequency for ANT2

Fig:4.6 shows the simulated result of VSWR. Compare with the centre-fed printed antenna with a rhombic slot (denoted as Ant. 1), good VSWR over a wider frequency range can be achieved by adopting an offset microstrip-fed line (denoted as Ant. 2).

VSWR

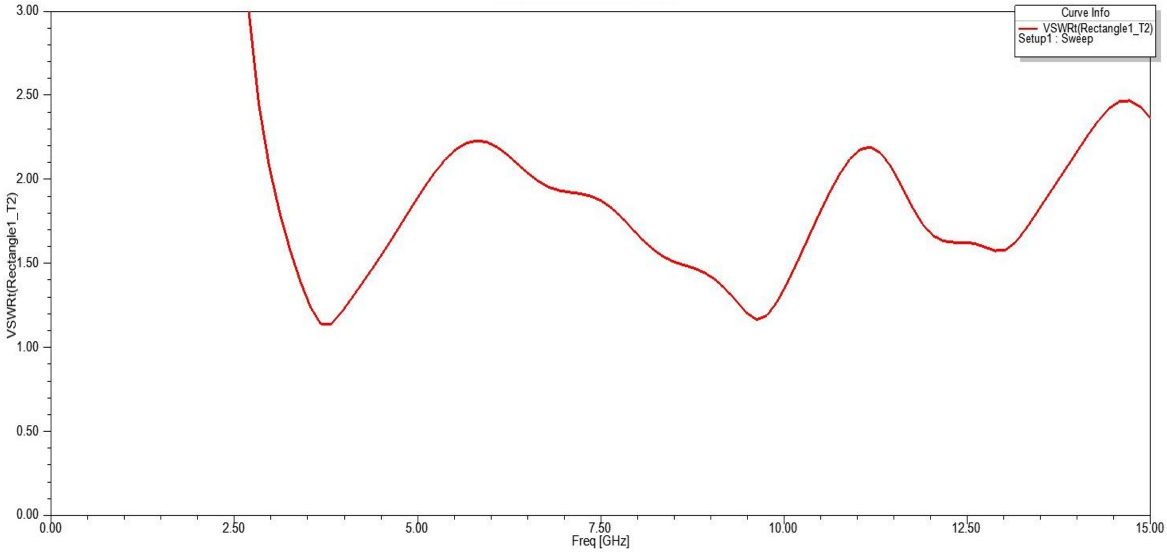


Fig 4.7: Variation of VSWR w.r.t frequency for ANT3

Fig:4.7 shows the simulated result of VSWR.

GAIN in dB:

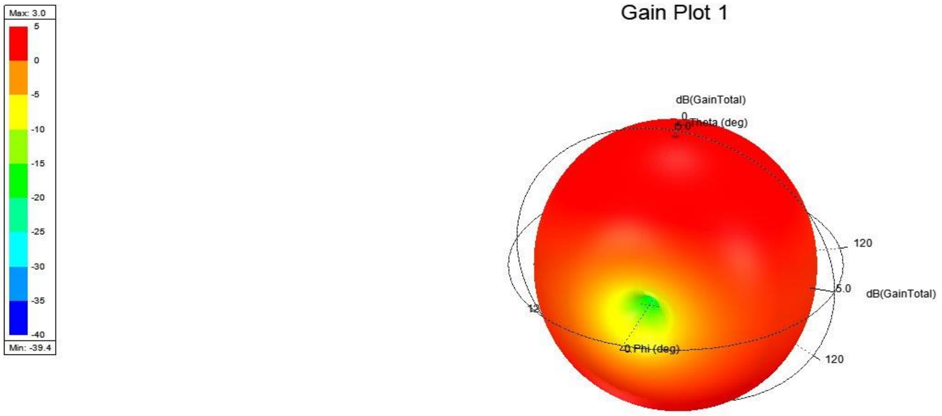


Fig 4.8 Gain in dB for ANT1

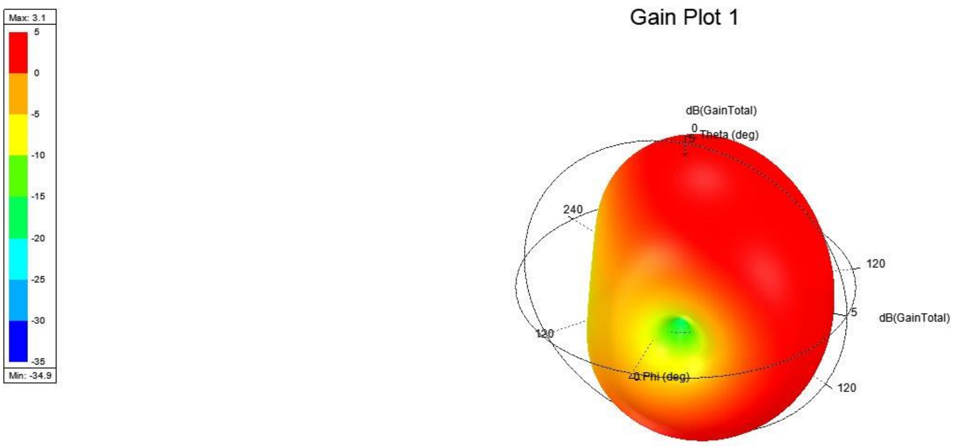


Fig 4.8 Gain in dB for ANT2

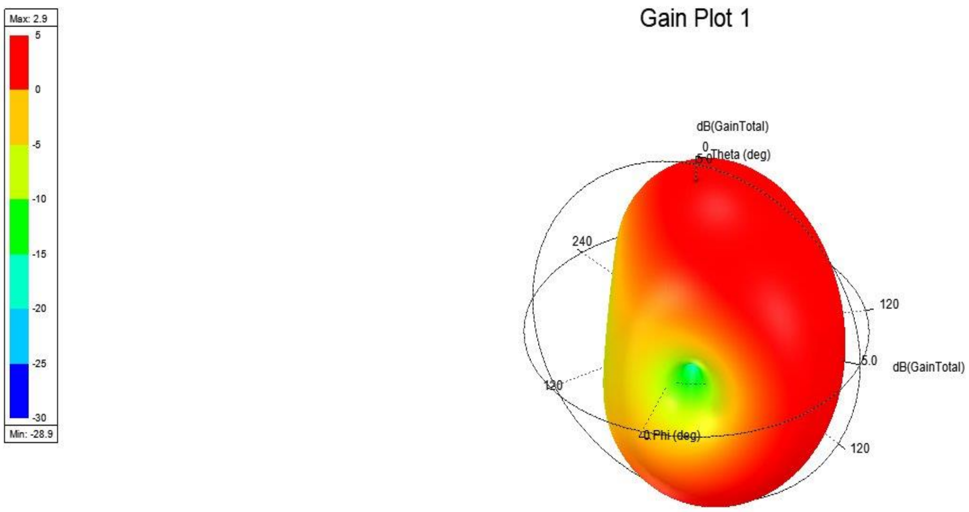


Fig 4.8 Gain in dB for ANT3

5.Design of MIMO Antenna for UWB Applications

5.1 Introduction:

Ingeneral, the design procedure for a band-notched antenna can be describedas follows. AUWB antenna without aband-notched function isdesigned to havegood impedance matching over the UWB, which is used as a reference antenna.Proposed resonant structures are added to the reference antenna to create notches atsome specific frequencies. The dimensions of the resonance structures can be used tocontrol the center frequencies and bandwidths of the notches. Different designs havebeen proposed to realize the band-notched characteristic for UWB planar monopoleantennas. These include using parasitic elements, folded strips, split-ring resonators(SRRs)quarter wavelengthtuning stubs,meander-ground structures,resonatedcellson the coplanar-waveguide, fractal tuning stub, slots on the radiator or ground, andslots or folded-strip lines along the antenna feed line. However, most of these designstargeted at creating a single-notched band and only one design targeted at a triple-notchedband usingmeander lines.

In this design two antenna elements placed perpendicular to each other to obtain polarization diversity,T shape strip used as decoupling structure. L shaped slits symmetrical to each other. Practically, the L shaped slits function as two parasitic elements and work as band stopfilters.Then, the band-notched propertyis achieved.

5.2 DesignSpecifications:

Thetwoessential parametersforthe design of anymicrostrippatch antenna are:

1. Dielectric Constant of the Substrate (ε_r): The dielectric material applied for thisdesign has a dielectric constant of 4.4, Use of a high dielectric constant can reduce thedimensionsoftheantenna,However,fortheradiationmodesmostusedsuchsubstratesresul tinelements,whichareelectricallysmallintermsoffree-spacewavelengthsandconsequentlyhaverelativelysmallerbandwidthsandlowefficiencies.

2. Height of dielectric substrate (h): The height of the dielectric substrate selectedhereis1.6mm.

Theessential parametersofthedesign areε_r =4.4 and h=1.6mm

5.3 UWB MIMO antenna without T strip:

Design of a MIMO antenna with T shape is done using HFSS and is as follows and it’sgeometric view is as shown in figure 5.1.Now we will see what happens if T strip not present in MIMO antenna. how it effects the performance of UWB MIMO antenna

5.3.1 Design ofUWB MIMO antenna without T strip:

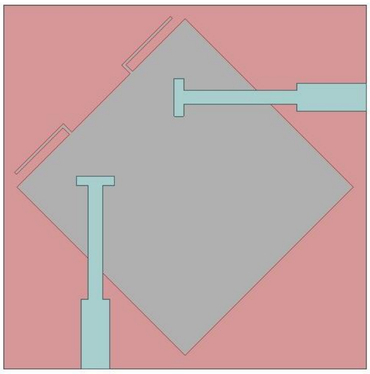


Fig 5.1(a) Top view of MIMO antenna

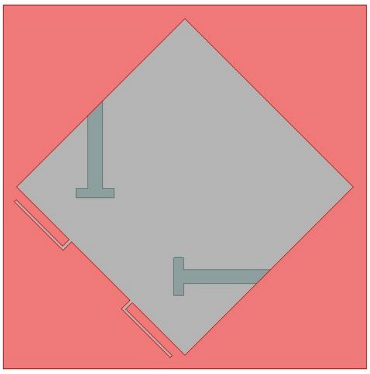


Fig5.1(b) Bottom view of MIMO antenna

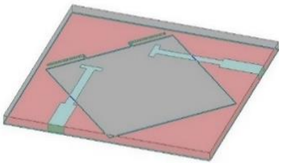


Fig 5.1(c) Trimetric view of MIMO antenna

Fig. 5.1 illustrates the geometry of the band-notched UWB MIMO antenna. The designed antenna with an overall size of 38.5 × 38.5 mm ^{2} is printed on an FR4 substrate with a thickness of 1.6 mm and a relative dielectric constant of 4.4. It consists of two orthogonal microstrip-fed lines, and a ground plane etched with a rhombic slot and a pair of L-shaped slits. Both the microstrip-fed lines at an offset distance from the center have three stages forimpedance transforming. The ground plane is designed on the other side of the substrate. The slits etched on thegroundareusedtoproduceanotchedbandat5.5GHz.The numerical analysis and geometry refinement of the antenna structure were carried out by using electromagnetic simulation software HFSS from ANSYS. Fig 5.1(b) and Fig 5.1(c) are the bottom view and trimetric view of the antenna respectively.

Table 5.1

ParametersofUWBantennawithout T shape

Design parameters	**Dimensions(mm)**
Ground length	38.5
Ground width	38.5
Substrate length	38.5
Substrate width	38.5
Substrate height	1.6
Diamond shape length	25.2
Diamond shape width	25.2
L shape parallel slit length	7.3
L shape perpendicular slit length	1.3
L shape slit width	0.3
Antenna element(lower) length	7.4
Antenna element(lower) width	3
Antenna element(middle) length	12
Antenna element(middle) width	1.5
Antenna element(top) length	1
Antennaelement(top) width	1

There are some other important parameters which can manipulate the results. Here we discuss distance between elements in UWB band notch Antenna Structure. The distance from edge of Diamond shape ground corner point is 19.25mm, the distance from diamond shape edge to antenna element is 8mm.

5.3.2 Antenna Without T strip results:

S11

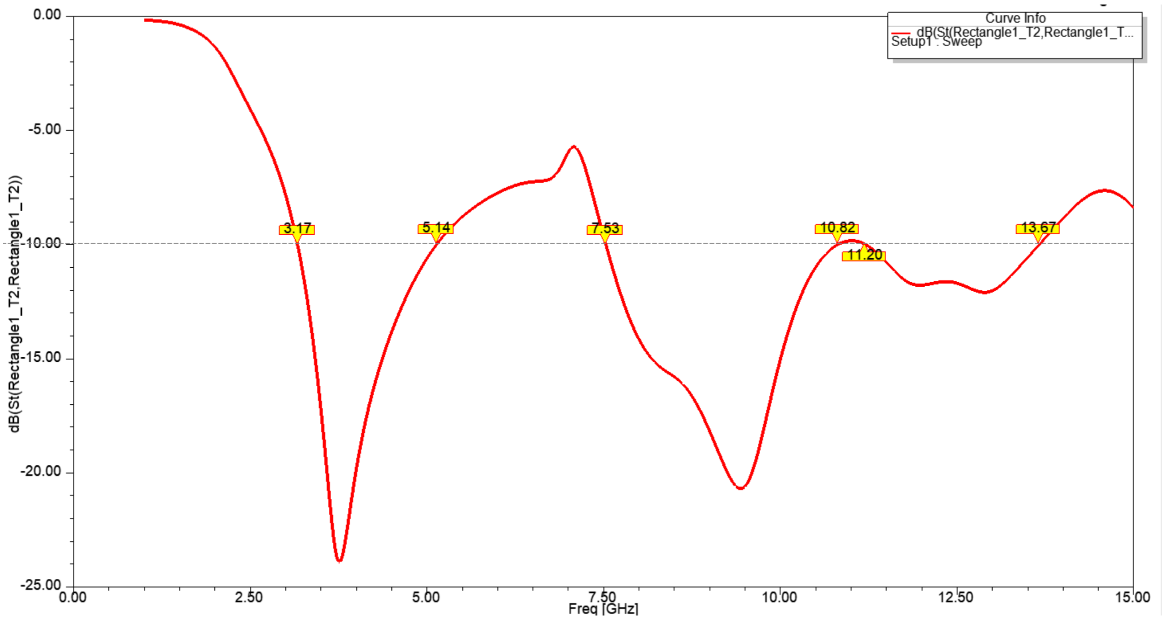


Fig 5.2: Returnloss(S11) variation w.r.t frequency without T strip

S12

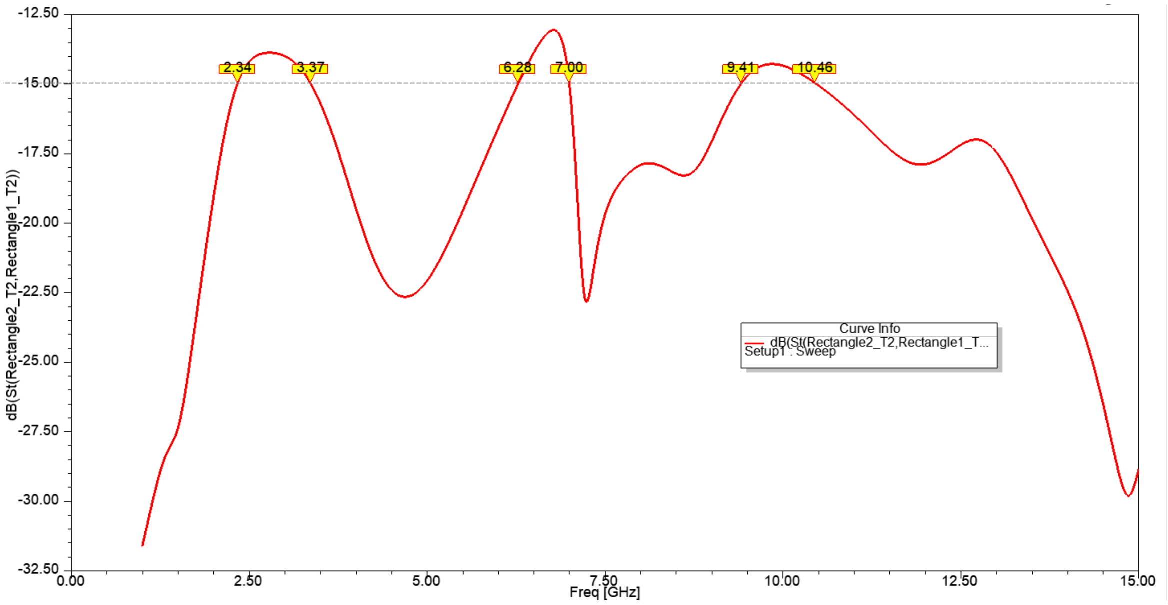


Fig 5.3:S12 variation w.r.t frequency without T strip

In above fig 5.2 we can see that UWB MIMO antenna rejecting the frequency band 5.14 to 7.53 GHz due to L shape slits on the ground. But in fig 5.3 we are seeing mutual coupling curve. Mutual coupling is typically undesirable in MIMO antenna. In order to provide good MIMO antenna, we have to minimize the mutual coupling.

Surface current distribution:

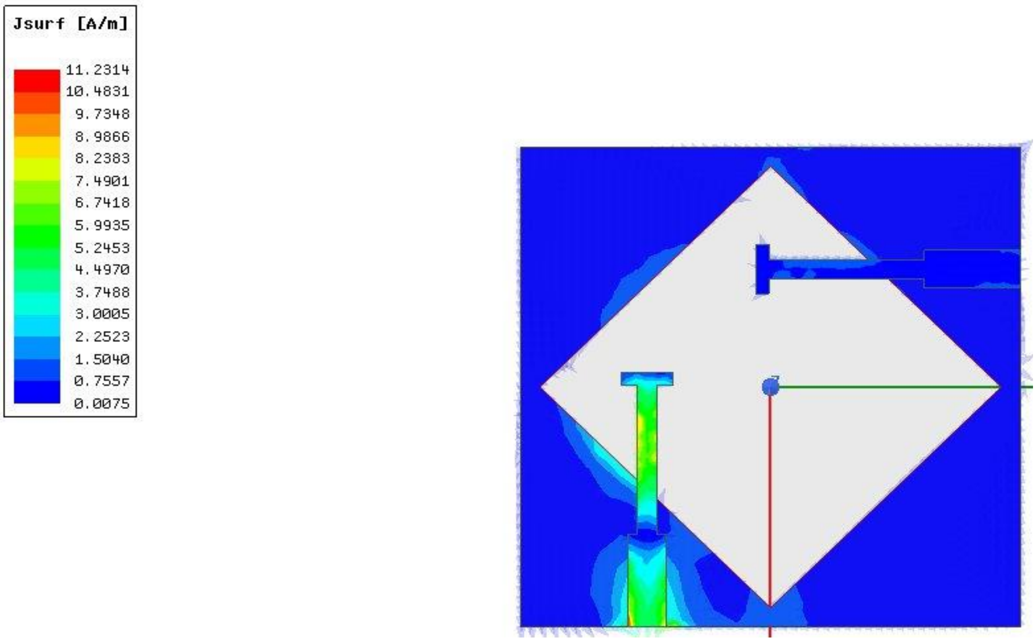


Fig5.4: Surface current distribution of antenna without T strip

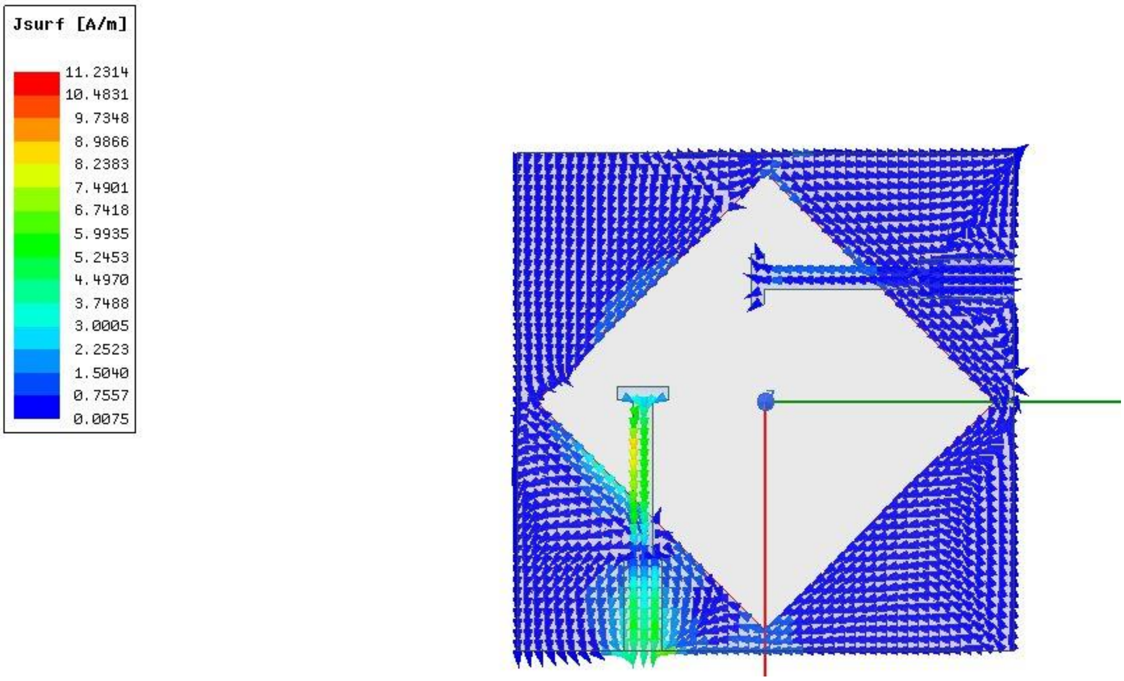
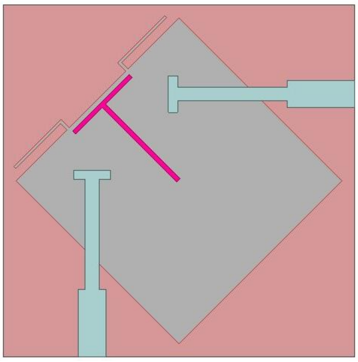


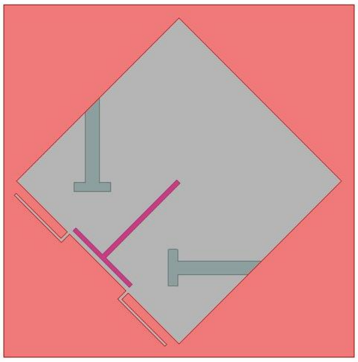
Fig 5.5: Vector current distribution of antenna without T strip

5.4 UWB MIMO antenna with T strip:

Design of a MIMO antenna with T shape is done using HFSS and is as follows and antenna geometric view is as shown in figure.

5.4.1 Design of UWB MIMO antenna with T strip:





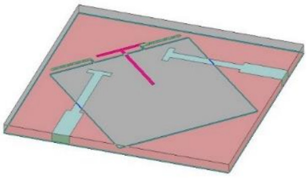


Fig 5.6(a)Top view of MIMO antenna

Fig 5.6(b) Bottom view of MIMO antenna

Fig 5.6(c) Trimetric view of MIMO antenna

Fig. 5.6 illustrates the geometry of the proposed band-notched UWB MIMO antenna. The designed antenna with an overall size of 38.5 × 38.5 mm ^{2} is printed on an FR4 substrate with a thickness of 1.6 mm and a relative dielectric constant of 4.4. It consists of two orthogonal microstrip-fed lines, a parasitic T-shaped strip, and a ground plane etched with a rhombic slot and a pair of L-shaped slits. Both the microstrip-fed lines at an offset distance from the center have three stages forimpedancetransforming. The parasitic strip placed between the antenna elements plays an important role in isolation improvement. It consists of two major parts: a strip along the diagonal and the other perpendicular to the diagonal. The ground plane is designed on the other side of the substrate. The slits etched on thegroundareusedtoproduceanotchedbandat5.5GHz.The numerical analysis and geometry refinement of the antenna structure were carried out by using electromagnetic simulation software HFSS from ANSYS.

In order to explain the band-notched function of the proposed MIMO antenna structure, we make surface current distribution and field analysis and then apply anequivalentparallelcircuitconcepttogiveguidancetoparameteroptimizations.Fig 5.6(b) and Fig 5.6(c) are the bottom view and trimetric view of the antenna respectively.

Thenotch frequency and the high order resonant frequencies increase. An increase in theVSWR at notch frequency. The able to reject the desired frequency. the L shaped slits used to define the band notch frequency and the T shape strip is helpful in decreasing the mutual coupling between antenna elements and increase the ECC. The antenna elements which are perpendicular to one another helps to obtain polarization diversity.

Table 5.2

ParametersofUWB MIMO antennawith T shape

Design parameters	**Dimensions(mm)**
T shape (perpendicular diamond shape) length	11.5
T shape (parallel to diamond shape) length	8.3
T shape width	0.5

Here we place the parasitic T strip between the antenna elements in such way that it can provide another path current flow to reduce mutual coupling. Table 2 shows dimensions of T strip. The Position of T strip also play important role in mutual coupling. There are some distances to consider while placing the T strip.From the point which antenna element cuts the diamond shape to origin of T shape is 12.35mm. The distance from plane side of diamond shape to origin of T shape is 12.6mm.

5.4.2 Simulation and Results of UWB MIMO antenna with T shape:

Parametricsweepresults:

In the parametric sweep, we simulate the design of different values of a parameter.This is useful in selecting the desired parameter value for the design. By selecting thebest results in the parametric sweep, with those parameter values, we will optimize forthebest results.

We can create a notch at any frequency in the UWB range by introducing the L shaped slits on the ground ofantennathatwasdesignedpreviouslyandbyvaryingtheparameters ofantenna alongwith thesizeand positioningof theslots.

L shape slit adjustment on MIMO antenna:

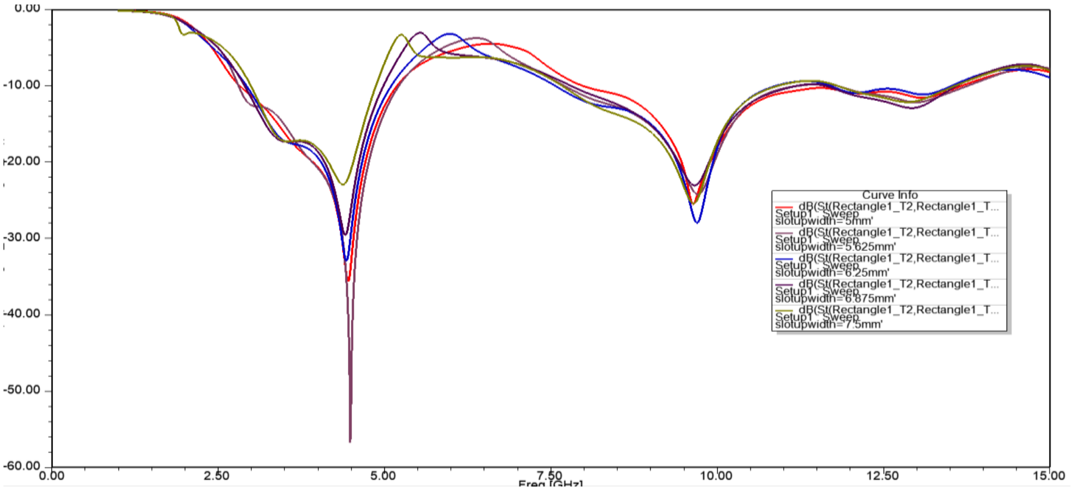


Fig 5.7: Variation ofreturn lossw.r.t frequencyforvalues ofwidth ofL shape slit on the ground

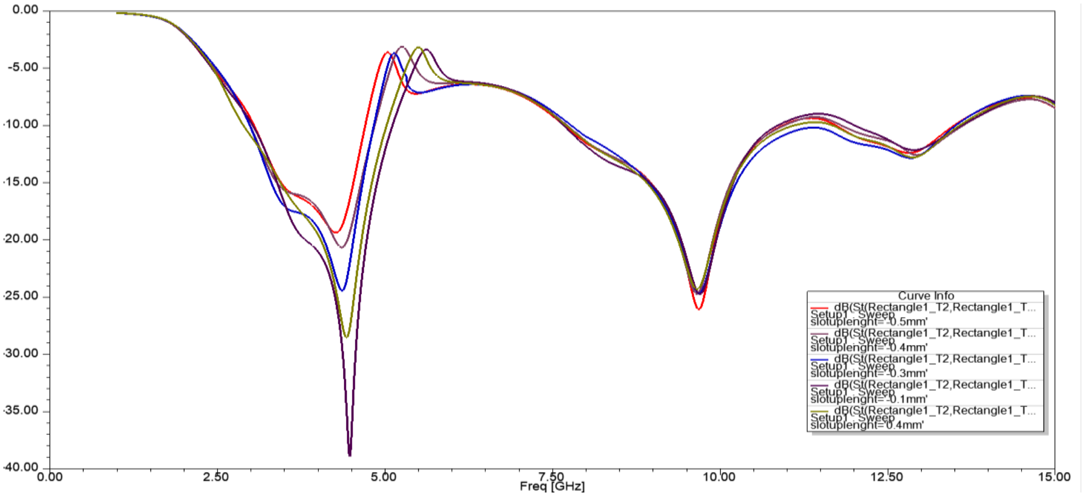


Fig5.8:Variation ofreturn lossw.r.t frequencyforvalues of length ofL shape slit on the ground.

In the fig 5.7 we vary the width from 5 mm to 7.5mm of L shape that is parallel to the diamond shape. this parametric sweep showing that in all cases it rejects the 5.15-5.85 GHz frequency band. In the fig 5.8 we vary the length from -0.5 to -0.1mm of L shape slit that is parallel to the diamond. We can clearly state that in all cases it providing a band notch for 5.15-5.85 GHz band.

Antenna with T strip Results:

S11

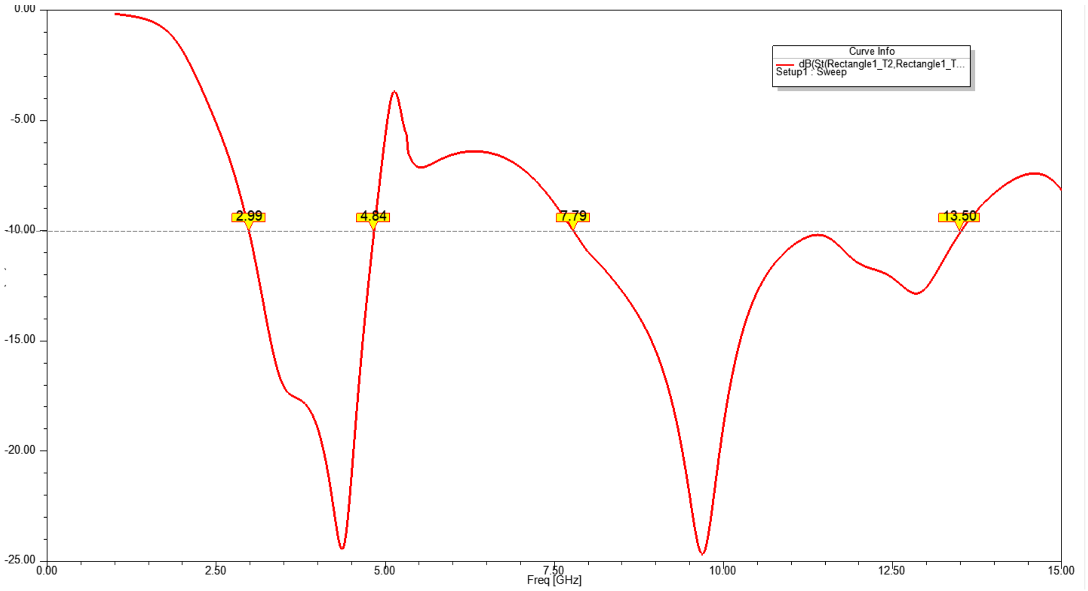


Fig5.9: return loss(s11) w.r.t frequencywith T strip

S12

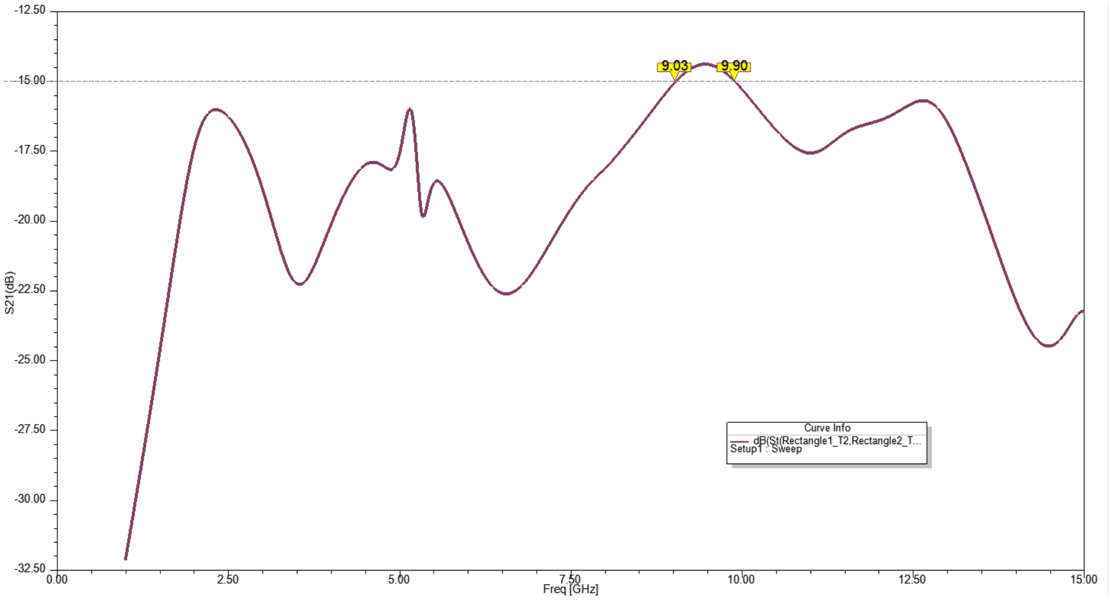


Fig 5.10: S12 w.r.t frequency with T strip

In fig 5.9 the S11 curve represents the return loss of UWB MIMO antenna. In the fig 5.4 the curve below -10 dB represents passing band. In range 4.84-7.79 GHz frequency the curve above -10 dB so we say that it rejecting the that frequency. In fig 5.10 S12 it showing mutual coupling curve is under 15dB. It providing low mutual coupling from

1to 9.03 GHz.So, T shape acting as decoupling structure. Which we got better results when we compared S12 without T shape

Surface current distribution:

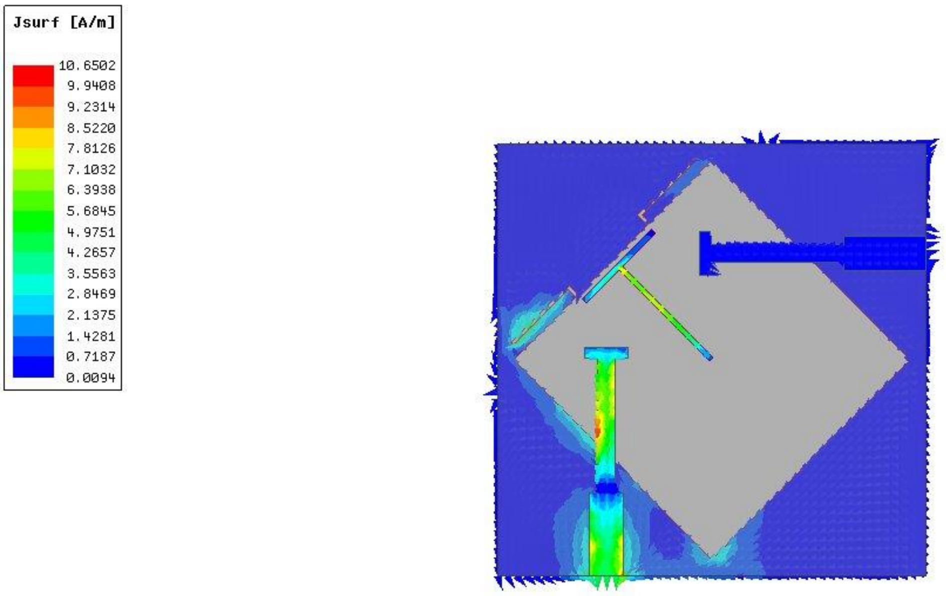


Fig 5.11: Magnitude surface current distribution

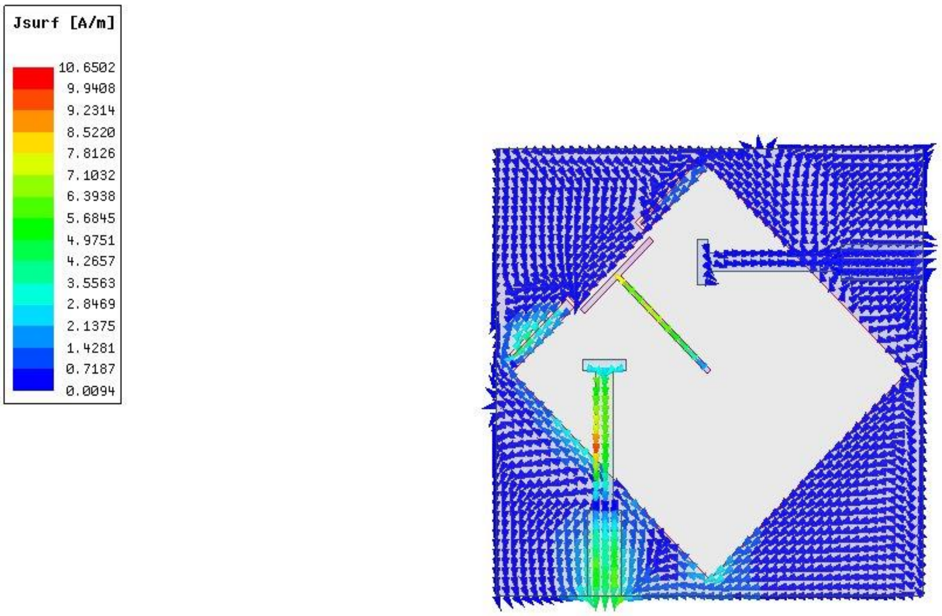


Fig 5.12: vector surface current distribution

VSWR:

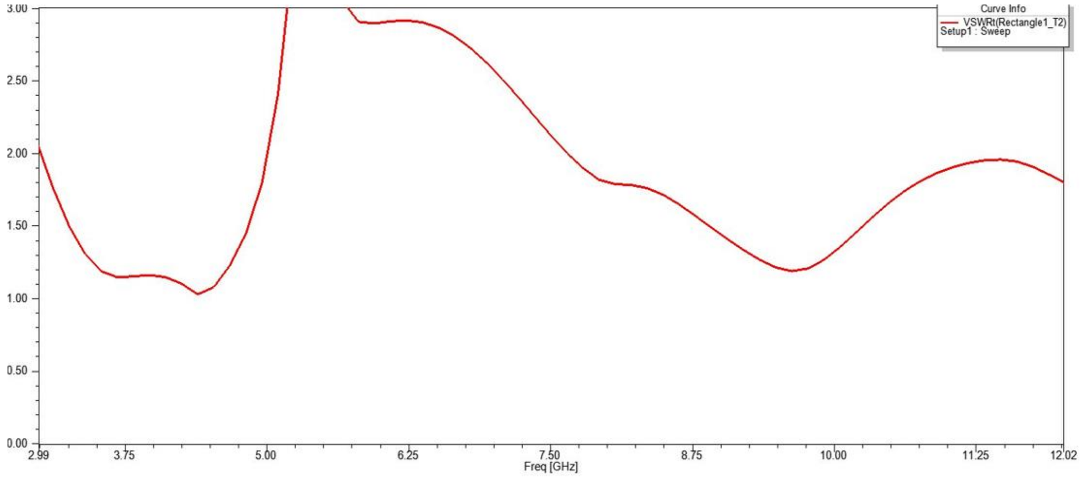


Fig5.13:Variation ofVSWR w.r.tfrequency

Fig 5.13 showing VSWR curve of UWB MIMO antenna with T strip. properly impedance matched antenna will have VSWR equal to one. The value ofVSWRforthefrequency5.15 to 5.85 GHz isgreaterthan2.In that band return loss is more than -10dB.

Gain:

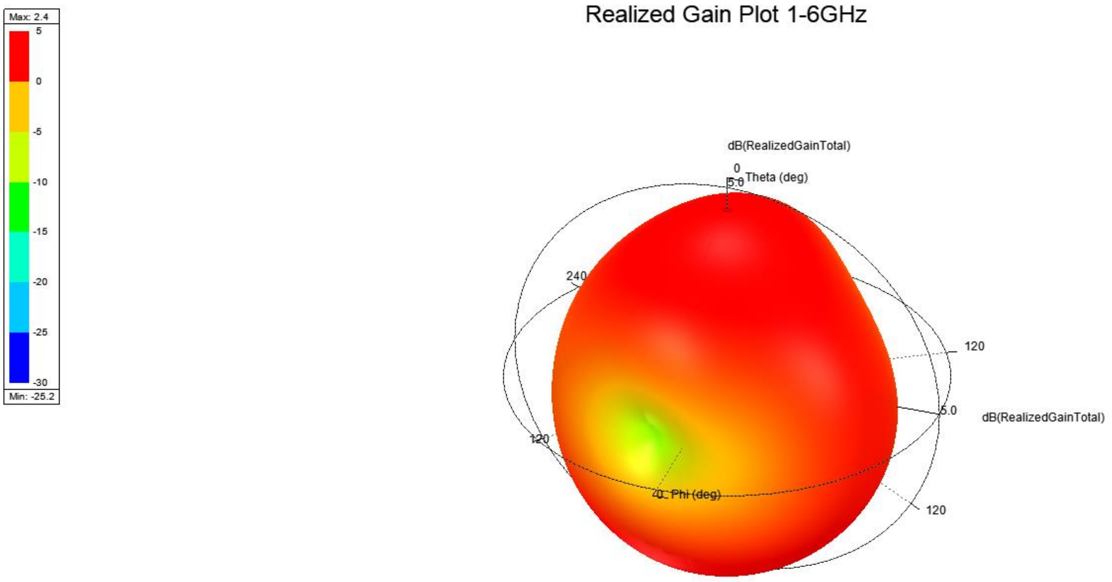


Fig 5.14: Gain of antenna with T strip

5.5UWB MIMO antenna with SRR:

5.5.1 Split ring resonator introduction:

A split-ring resonator (SRR) is an artificially produced structure common to metamaterials Their purpose is to produce the desired magnetic susceptibility (magnetic response) in various types of metamaterials up to 200 Terahertz These media create the necessary strong magnetic coupling to an applied electromagnetic field, not otherwise available in conventional materials. For example, an effect such as negative permeability is produced with a periodic array of split ring resonators.

A single cell SRR has a pair of enclosed loops with splits in them at opposite ends. The loops are made of nonmagnetic metal like copper and have a small gap between them. The loops can be concentric, or square, and gapped as needed. A magnetic flux penetrating the metal rings will induce rotating currents in the rings, which produce their own flux to enhance or oppose the incident field (depending on the SRRs resonant properties). This field pattern is dipolar. The small gaps between the rings produces large capacitance values which lower the resonating frequency. Hence the dimensions of the structure are small compared to the resonant wavelength. This results in low radiative losses, and very high-quality factors.

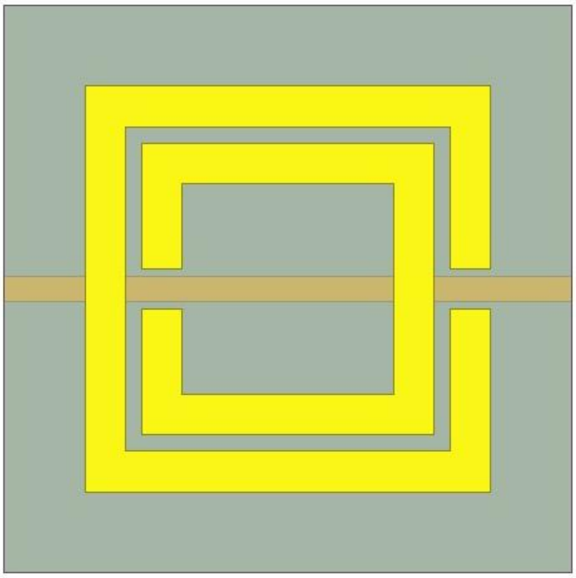


Fig 5.15: split ring resonator

5.5.2 Design of UWB MIMO antenna with SRR:

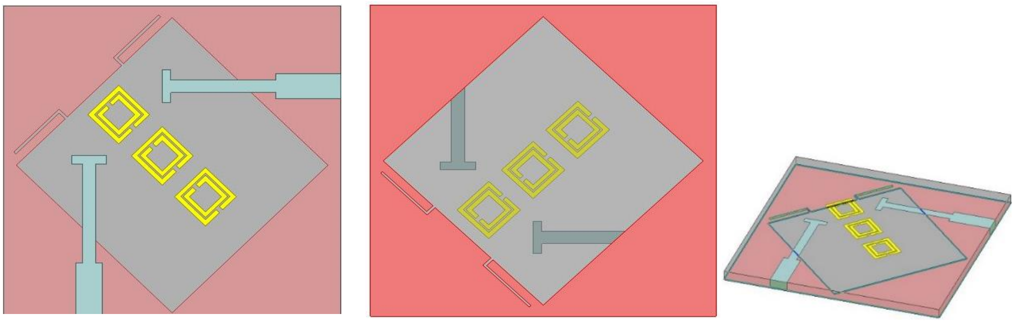


Fig 5.16 :(a) Top view(b) Bottom view(c) Trimetricview of MIMO antenna with SRR

This UWB MIMO antenna with SRR can easily designed by removing T strip from MIMO antenna with T strip using stimulation software HFSS from ANSYS. In this antenna structure we obtain Notch band characteristics but mutual coupling is similar antenna elements UWB MIMO antenna with T strip. In designing split ring resonator mainly two steps 1. Designing of outer ring and 2. Designing of inner ring. By adjusting the outer ring and inner ring width and length we can made split ring resonator as decoupling structure like parasitic T strip. Which provide alternative path for surface current flow.

5.5.3 Antenna with SRR Results:

S11

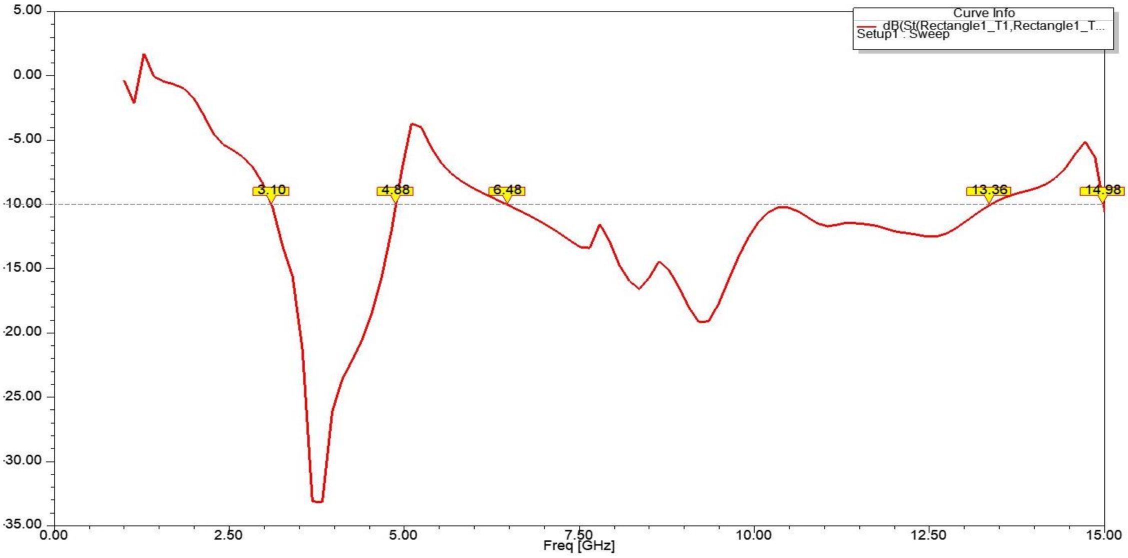


Fig 5.17: Return loss (S11) w.r.t frequency

S12

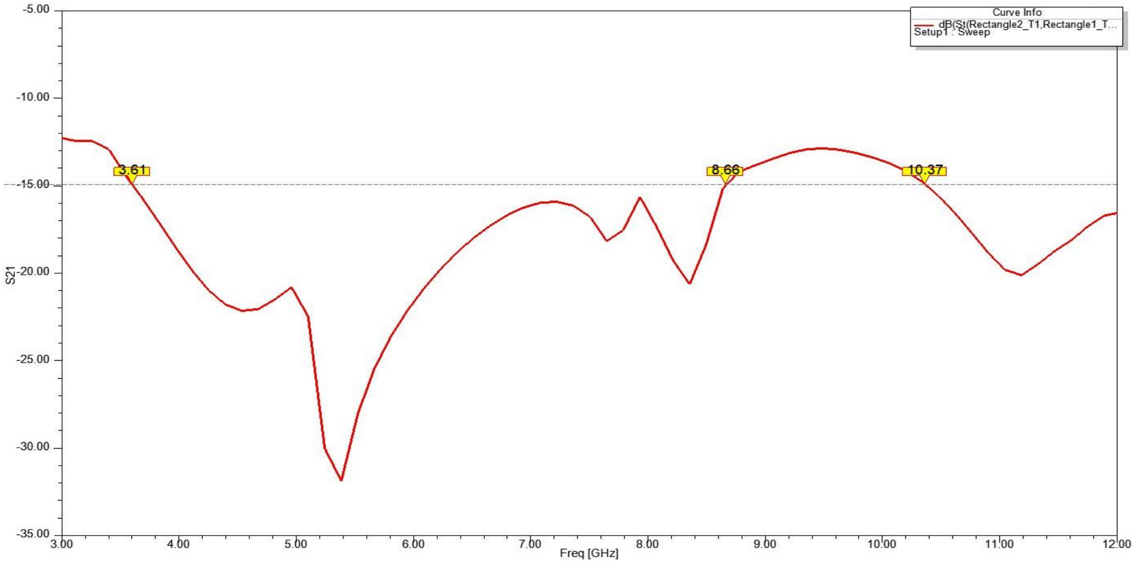


Fig 5.18: S12 w.r.t frequency

In fig 5.17 the S11 curve represents the return loss of UWB MIMO antenna. In the fig 5.4 the curve below -10 dB represents passing band. In range 4.88-6.88 GHz frequency the curve above -10 dB so we say that it rejecting the required band. In fig 5.18 S12 it showing mutual coupling curve. It providing low mutual coupling from 3.61 to 8.66 GHz. The curve is under -15dB.So SRR acting as decoupling structure.

Surface Current distribution:

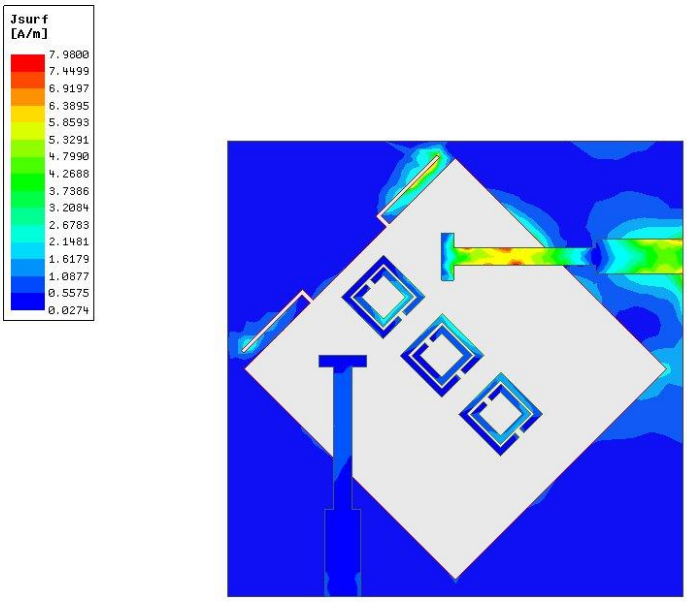


Fig 5.19: Magnitude surface current distribution

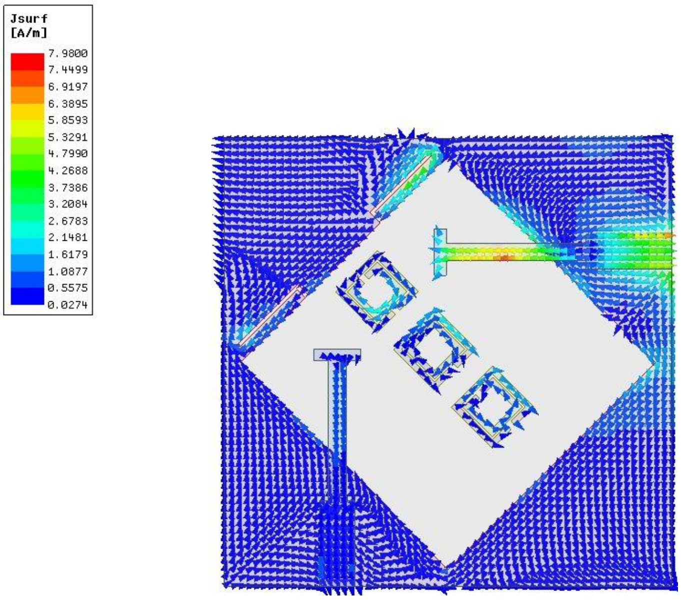


Fig 5.20: Vector surface current distribution

VSWR:

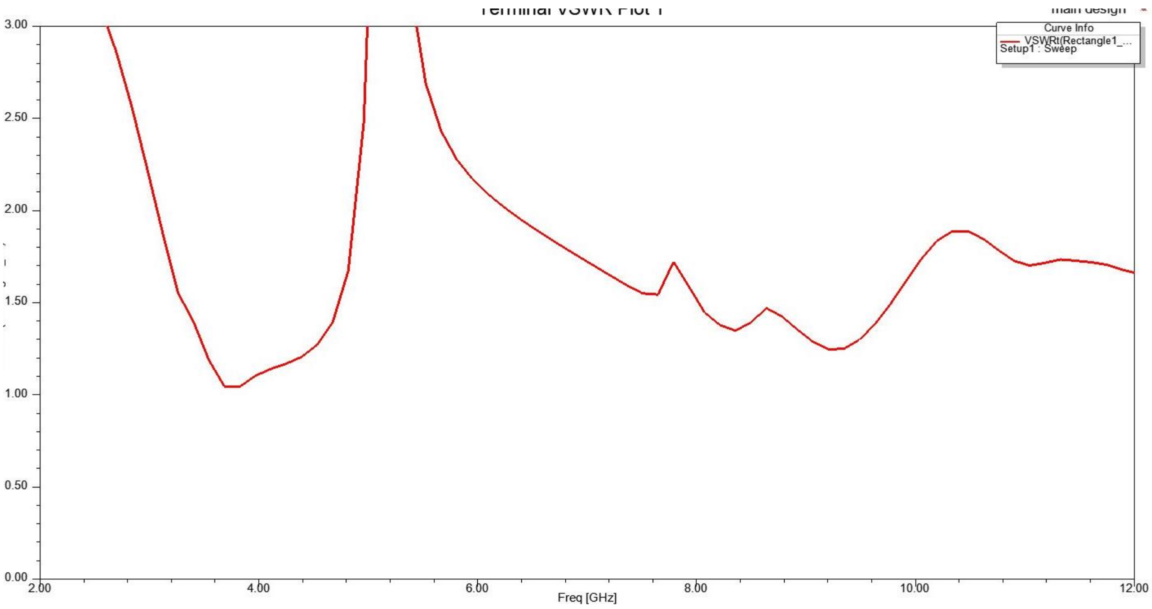


Fig 5.21:Variation ofVSWR w.r.tfrequency

Fig 5.21 showing VSWR curve of UWB MIMO antenna with SSR. A properly impedance matched antenna will have VSWR equal to one. The value ofVSWRforthefrequency5.15 to 5.85 GHz isgreaterthan2.In that frequency band return loss is more than -10dB.

Gain:

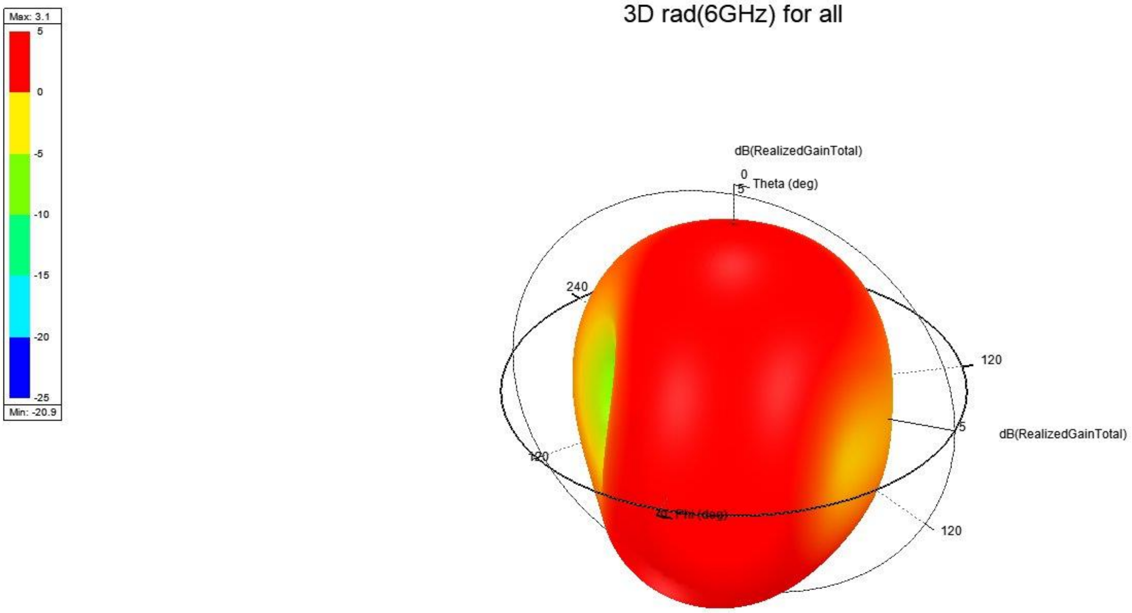
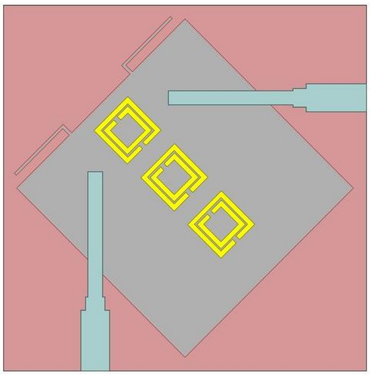


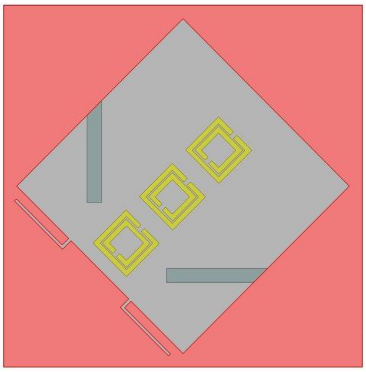
Fig 5.22: Gain of antenna with SRR

5.6UWB MIMO Antenna with band notch characteristics:

We have designed the UWB MIMO antennas with parasitic T strip, SRR and antenna elements. From results we can conclude that T strip and SRR acts as a good decoupling structure but the notch band is more than wireless operating frequency band. It may cause loss of information while receiving signals and sending signals from the antenna. We made changes to the antenna so that antenna able to provide desired notch band and less mutual coupling between antenna elements in MIMO antenna. Design of a MIMO antenna with T shape is done using HFSS and is as follows and antenna geometric view is as shown in figure.

5.6.1 Final design of UWB MIMO antenna:





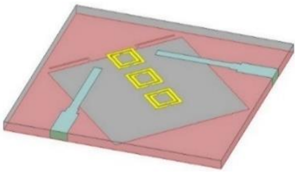


Fig 5.23(a):Top viewof Fig 5.23(b):Bottom view of Fig
5.23(c):TrimetricMIMO antenna MIMO antenna view of MIMO
antenna

Fig 5.23 illustrates the geometry of the proposed band-notched UWB MIMO antenna. The designed antenna with an overall size of 38.5 × 38.5 mm ^{2} is printed on an FR4 substrate with a thickness of 1.6 mm and a relative dielectric constant of 4.4. It consists of two orthogonal microstrip-fed lines, a split ring resonator, and a ground plane etched with a rhombic slot and a pair of L-shaped slits. Both the microstrip-fed lines at an offset distance from the center have three stages forimpedancetransforming. The parasitic strip placed between the antenna elements plays an important role in isolation improvement. It consists of two major parts: a strip along the diagonal and the other perpendicular to the diagonal. The ground plane is designed on the other side of the substrate. The slits etched on thegroundareusedtoproduceanotchedbandat5.5GHz.The numerical analysis and geometry refinement of the antenna structure were carried out by using electromagnetic simulation software HFSS from ANSYS.

Fig 5.23(b) and Fig 5.23(c) are the bottom view and trimetric view of the antenna respectively. Thenotch frequency and the high order resonant frequencies increase. An increase in theVSWR at notch frequency. The able to reject the desired frequency. the L shaped slits used to define the band notch frequency and the T shape strip is helpful in decreasing the mutual coupling between antenna elements and increase the ECC. The antenna elements which are perpendicular to one another helps to obtain polarization diversity.

Table 5.3

ParametersofUWB MIMO antenna

Design parameters	**Dimensions(mm)**
Ground length	38.5
Ground width	38.5
Substrate length	38.5
Substrate width	38.5
Substrate height	1.6
Diamond shape length	25.2
Diamond shape width	25.2
L shape parallel slit length	7.3
L shape perpendicular slit length	1.3
L shape slit width	0.3
Antenna element(lower) length	6.4
Antenna element(lower) width	3
Antenna element(middle) length	1.3888
Antenna element(middle) width	2
Antenna element(top) length	13.222
Antennaelement(top) width	1.5
SRR inner ring length	4
SRR inner ring width	4
SRR outer ring length	5
SRR outer ring width	5
SRR ring thickness	1

The distance between two split ring resonator is 2 mm. the distance between two L shaped slits is 8.3 mm.The distance between L shaped slits diamond side to Split ring resonator is 2.19 mm.The distance between two rings in SRR is 0.5 mm. From the point which antenna element cuts the diamond shape to SRR is 10.35mm.

5.6.2 Results of UWB MIMO Antenna:

S11

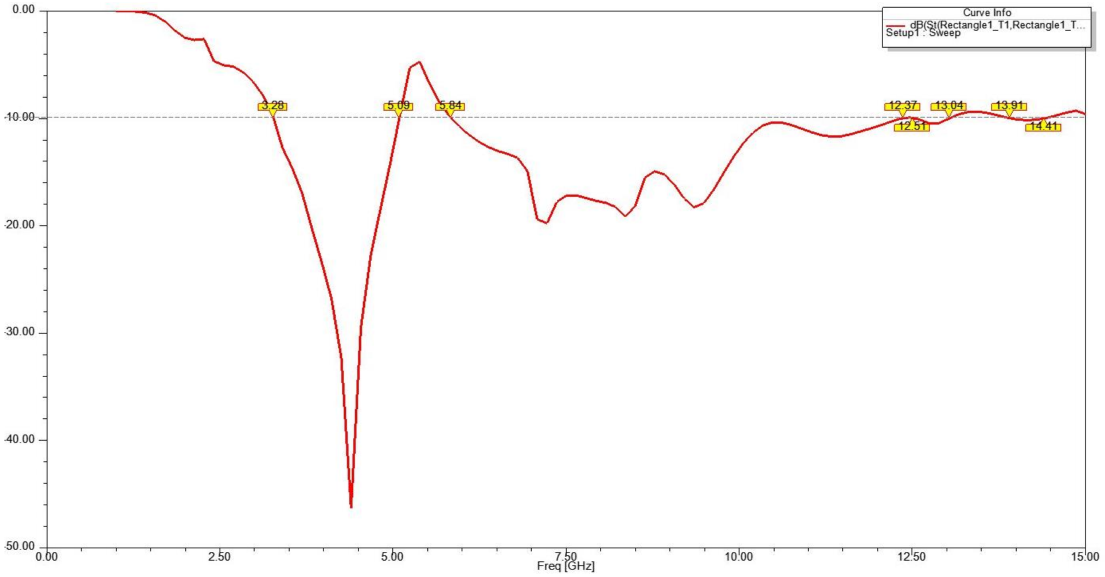


Fig 5.24: Return loss (S11) w.r.t frequency

S21

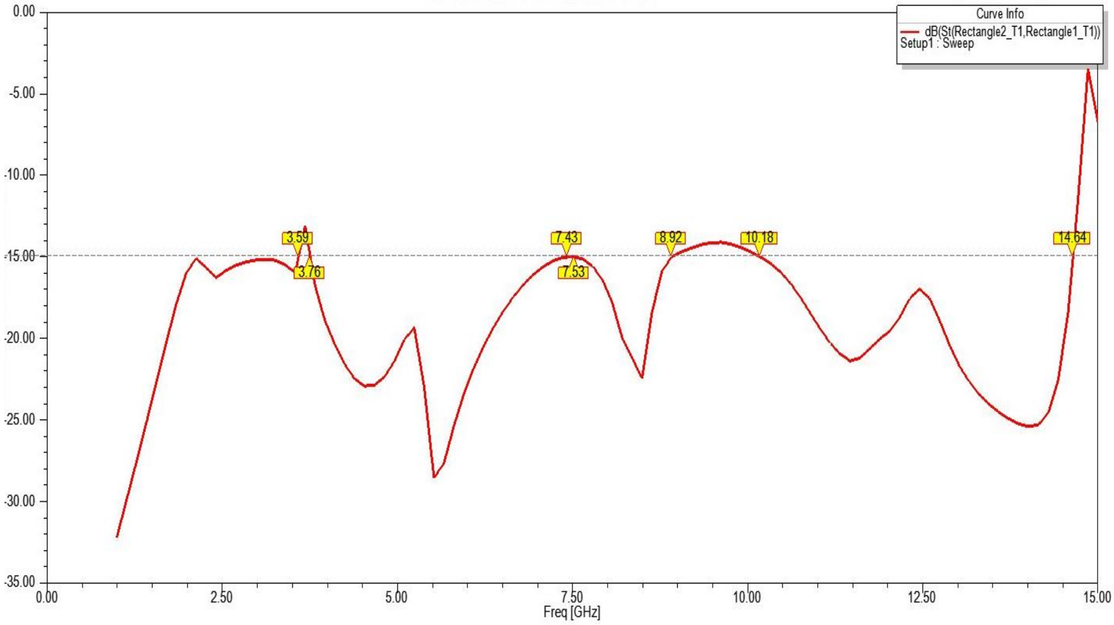


Fig 5.25: S12 w.r.t frequency

In fig 5.24 the S11 curve represents the return loss of UWB MIMO antenna. In the fig 5.21 the curve below -10 dB represents passing band. In range of 5-6 GHz frequency the curve is above -10 dB so we say that it rejecting the required frequency band. In fig 5.25 S12 it showing mutual coupling curve. It providing low mutual coupling from 3.76 to 7.43 GHz and 7.53 to 8.92 GHz. The curve is under 15dB.So SRR acting as decoupling structure.

Surface Current distribution:

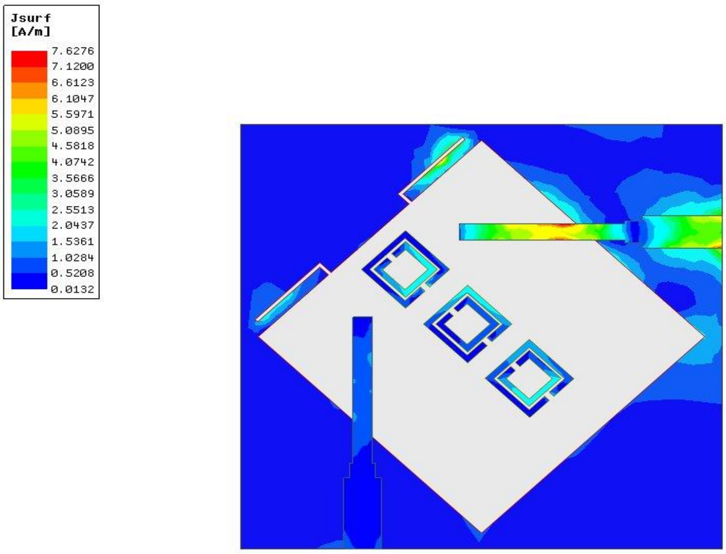


Fig 5.26: Magnitude surface current distribution

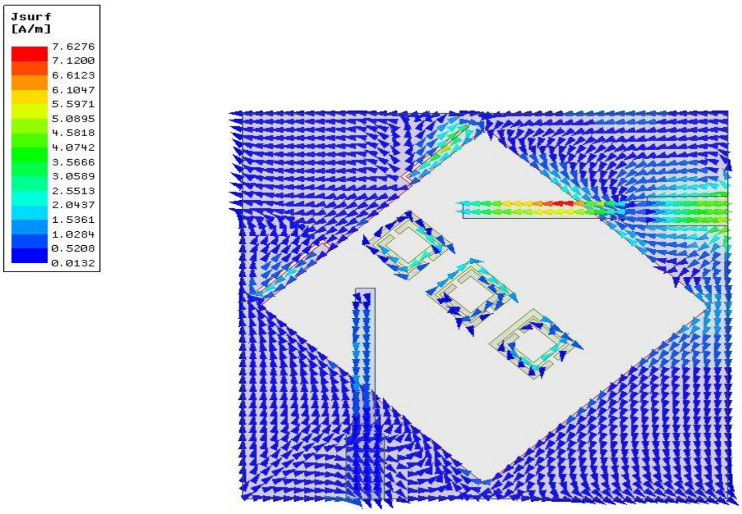


Fig 5.27: Vector surface current distribution

VSWR:

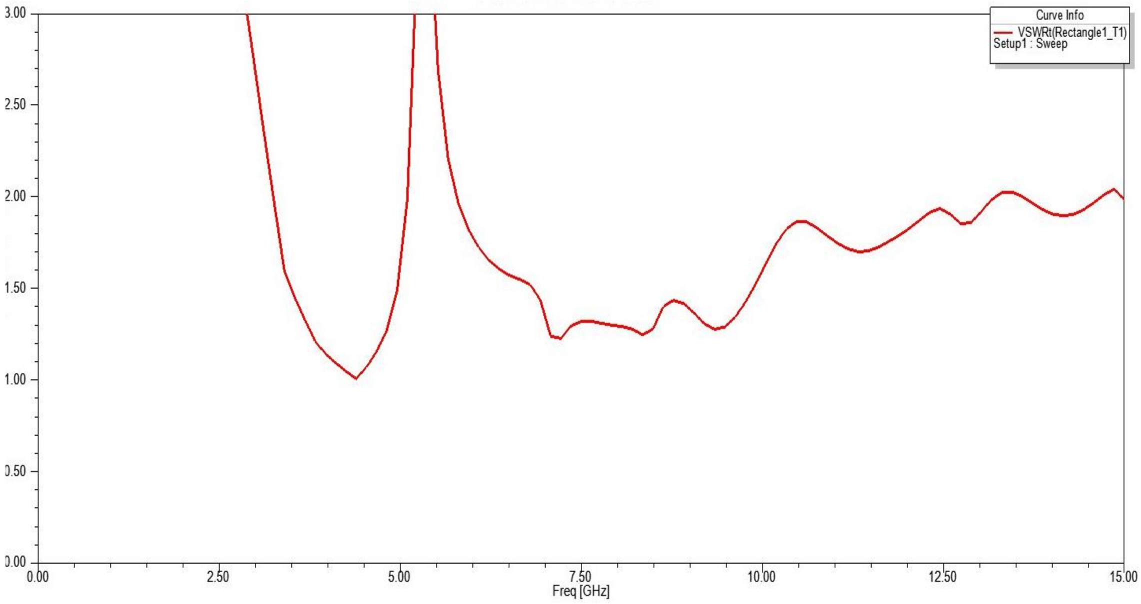


Fig5.28:Variation ofVSWR w.r.tfrequency

Fig 5.28 showing VSWR curve of UWB MIMO antenna with split ring resonator. properly impedance matched antenna will have VSWR equal to one. The value ofVSWRforthefrequency5.15 to 5.85 GHz isgreaterthan2.In that frequency band return loss is more than -10dB.

Realized gain:

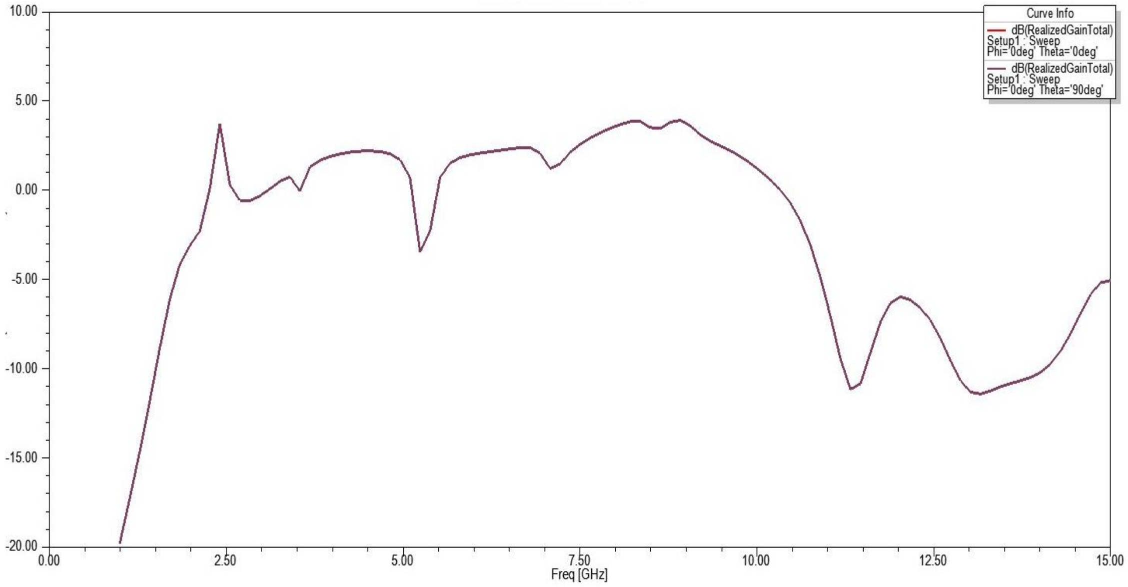


Fig5.29: realized gain w.r.t frequency

Gain:

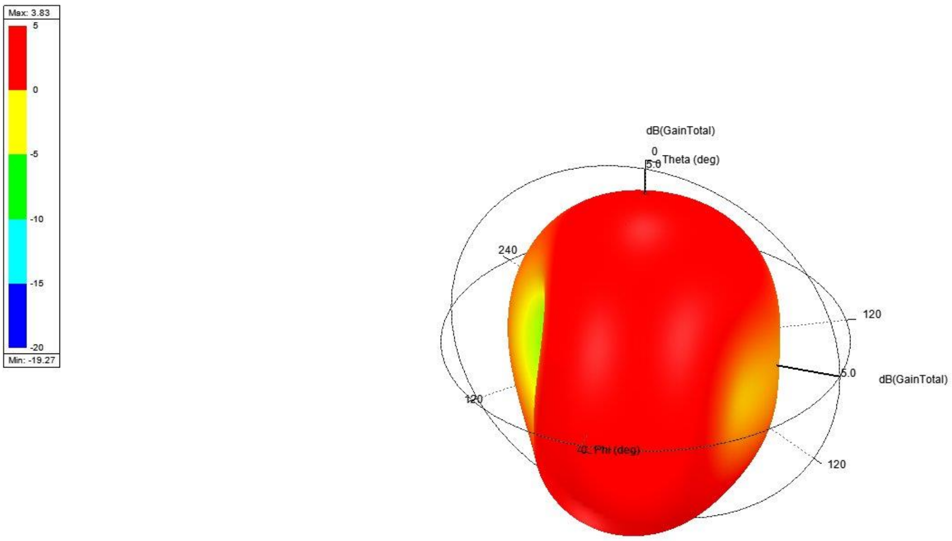


Fig 5.30: Gain of antenna at 6 GHZ

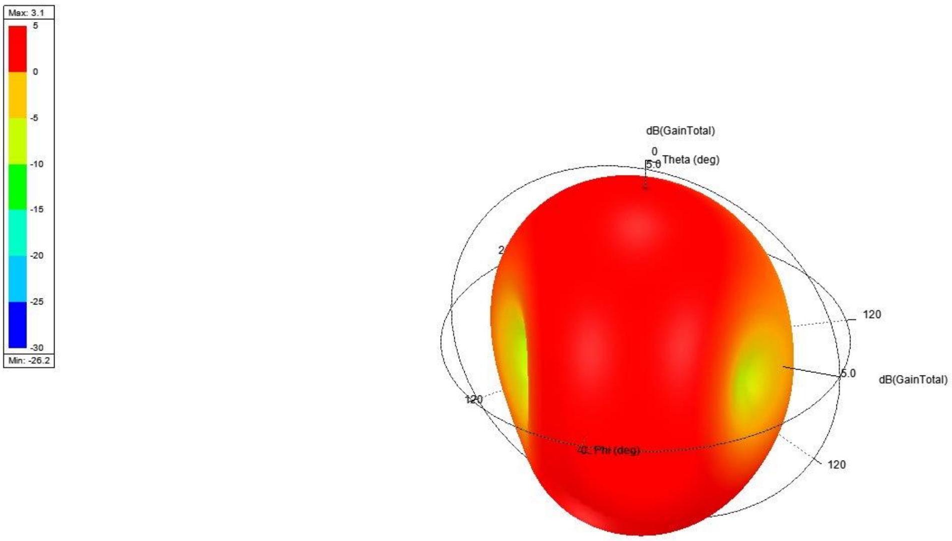


Fig 5.31: Gain of antenna at 4.5 GHZ

6.Conclusion

In the project, we have designed a basic rectangular microstrip patch antenna thatworks in the UWB range. i.e 3.1 t0 10.6 GHz. The proposed antenna has asimple geometry and design process.The proposed antenna uses very low energy forshort-range and high bandwidth communication for over a large portion of the radiospectrum.The offset microstrip-fed lines are employed to feed the antenna with wideband impedance matching. The return loss is below -10dB and VSWR are well below the mark (VSWR less than 2) for the operatingfrequencyrangeof UWB (3.1-10.6 GHz).

UWB MIMO antenna with band-notchedcharacteristicshas been designed to create a notch (at 5 to 6 GHz) in the UWBrange where Wi-Fi applications that were also used.This may causeinterference in the signals. To reduce this destructive interference notch is included inthisantennabyintroducingslits in theground ofthe antenna.Portisolation is improved by using a simple decoupling structure

VSWR is greater than 2 and return loss more than -10dB at rejection frequency band (5 to 6GHz).The antenna elements in the antenna helps to perform polarization diversity.With the features mentioned above and a compact size, the proposed antenna can be a promising candidate for MIMO/diversitysystems.